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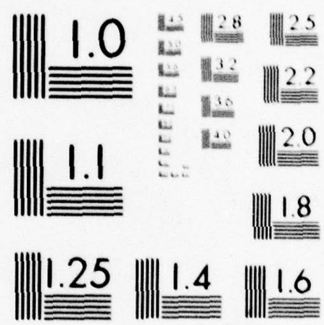
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TECHNICAL REPORT EL-79-3

PLAN FOR DEVELOPMENT OF SYSTEMATIC PROCEDURES TO AID CORPS DISTRICTS IN FLOOD DAMAGE CALCULATIONS

by

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The study of alternative structural and nonstructural approaches to reducing flood damages is a major Corps activity. A plan was prepared, with Corps Districts and Divisions input, for upgrading and enhancing existing Corps flood damage estimation capabilities with no departure from accepted Corps concepts or general methodologies. The plan takes advantage of many available technical tools and is directed to the streamlining and standardizing of

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20. ABSTRACT (Continued)

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acquisition, processing, and storage of data; the calculation of residential, commercial, industrial, agricultural, and land-use type damages; and the aggregation of calculation results on single flood, flood zones, and average annual bases.

PREFACE

This study was sponsored by the Flood Plain Management Services Branch (DAEN-CWP-F), Office, Chief of Engineers, Washington, D. C. The purpose of the study was to formulate a plan for upgrading Corps Districts' capabilities to perform flood damage calculations. Although there is no arrangement as yet to implement the plan, some aspects of the plan are being pursued in a development study being performed by the U. S. Army Engineer Waterways Experiment Station (WES) for the Flood-plain Information Services Branch, Memphis District.

The study was conducted during the period April-December 1977 by Dr. Victor E. LaGarde of WES under the general supervision of Messrs. W. G. Shockley, Chief, Mobility and Environmental Systems Laboratory (MESL), and B. O. Benn, Chief, Environmental Systems Division (ESD), MESL. Due to reorganization in April 1978, the ESD is now part of the Environmental Laboratory of which Dr. John Harrison is Chief. This report was written by Dr. LaGarde.

Mr. Ted McDonald, Economics Branch, Mobile District, Corps of Engineers, Mobile, Alabama, provided particularly valuable assistance in the study. Appreciation is given to the many persons, primarily those on Corps Division and District staffs, who provided information during the course of the study. Information exchange was provided by telephone conversations, informal meetings, and in-depth technical discussions with economics, floodplain management, and hydraulics staffs. In addition to the Bureau of Reclamation, Denver Regional Office, and the U. S. Army Engineer Hydrologic Engineering Center, personnel of the following Corps Divisions and Districts were contacted: Lower Mississippi Valley Division, North Central Division, New England Division, Vicksburg District, Mobile District, Fort Worth District, Kansas City District, New Orleans District, Los Angeles District, Huntington District, Memphis District, Jacksonville District, Tulsa District, and Portland District.

Director of WES during the study and preparation of the report was COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	4046.856	square metres
feet	0.3048	metres
square miles	2.589988	square kilometres

PLAN FOR DEVELOPMENT OF SYSTEMATIC PROCEDURES TO AID CORPS DISTRICTS IN FLOOD DAMAGE CALCULATIONS

PART I: INTRODUCTION

Background

1. The planning for the conservation, development, and management of water and related land resources involves a multiobjective approach. Objectives* of National Economic Development and Environmental Quality, and in some cases, Regional Development and Social Well-Being must be appraised in water resource programs and projects undertaken by the Corps of Engineers. Both structural and nonstructural plans must be considered in the systematic preparation and evaluation of various alternative measures for responding to the problems, needs, concerns, and opportunities of the desired goals under the objectives.

2. Increases in earnings through a reduced disruption of economic activity due to flooding remains an area of major concern to the Corps as part of the National Economic Development objective. The prevention or reduction in flooding arising from stream overflow, high tides, inadequate drainage, and overland flow is directly considered by the Corps, as well as indirect adjustments to the type of floodplain use in flood hazard areas. The benefits from the reduction in flooding in a given situation can be placed in the following benefit categories:

   a. Inundation reduction. All activities using the floodplain which show a net income increase (decrease also considered) due to adoption of an inundation reduction plan are considered. Activities not presently on the floodplain are considered if the projected net income due to relocation on the floodplain with the adoption of the plan is larger than the income at an alternative site off the floodplain without the plan.

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* Engineer Regulation 1105-2-351.

b. Intensification. All business (nonresidential) activities which intensify operations on the protected floodplain because a reduction in flood hazard makes it profitable to do so are considered. The benefit is the profit difference between present operations and intensified operations as opposed to increasing production by other means at an alternate location.

c. Location. An activity is considered if it would take place on the floodplain with but not without protection. Benefit is the net income difference between location on or off the floodplain with an accompanying decrease in production in the activity being replaced on the floodplain.

3. Flood damage analysis comprises a major part of the inundation reduction benefit considerations and can be an important factor in intensification and location benefit considerations. A flood damage analysis is performed, in varying detail, for all Corps flood control studies depending on study type and whether the study is done before or after the project is authorized.

4. The preauthorization analyses include the Reconnaissance, Detailed Project, Survey, and Special studies. Postauthorization studies include the Phase I and Phase II General Design Memorandum studies. Section 205, Small Flood Control; Section 208, Snagging and Clearing; Section 14, Emergency Streambank and Shoreline Protection; and Post-Disaster studies under the Flood Control Act of 1974 are included in the continuing authorization studies. The general objective of each study type is described briefly below with emphasis on the flood damage aspect of the study.

Preauthorization studies

5. Reconnaissance. This study is used to identify flood-associated problems. The primary study objective is to determine if the Corps has the authority and rationale to pursue alternative solutions to flood problems. Economic rationality and feasibility for a solution are addressed using hydrologic and economic data that have been generalized for the region of interest. The study is normally undertaken entirely by the study manager in consultation with an

economist and environmentalist. The reconnaissance report containing the study results is usually quite brief.

6. Detailed Project. If the reconnaissance study demonstrates that there are problems and that the Corps has the authority and rationale to pursue solutions that appear economically feasible under the continuing authorities of Sections 205 or 208, then a Detailed Project study is initiated. The general objective is to evaluate alternative solutions and verify the economic rationality of a specific solution for public or sponsor acceptance. Detailed Project studies can serve as the basis for approval of a project for construction by the Chief of Engineers and for preparation of contract plans and specifications. This type of study usually involves field investigations as well as the analysis of available data to generate quantitative hydrologic and damage data. Normally, the interdisciplinary team concept must be employed, where the team should be composed of a study manager, economist, environmentalist, and biologist. A detailed report is prepared.

7. Survey. The Survey study is performed for decision-making purposes concerning the need for and desirability of undertaking specific projects and programs. This is the largest class of Corps implementation studies and includes all those reports to Congress for authorization action. They are referred to as review studies when the study authority directs the review of a previous study effort. They are referred to as Interim studies when accomplished as a partial implementation of a larger survey scope planning effort.

8. Special. Special studies are sometimes required for a special consideration of various improvement plans including future development, relocations, and increased flooding caused by flow-restricting structures or upstream conditions. Carried out with the cooperation of other Federal and state agencies, the study detail can vary from that of a Reconnaissance to a Survey study. Special studies may range in scope from a detailed study of a very restricted area within the floodplain to a generalized study of a large geographic region.

Postauthorization studies

9. Phase I General Design Memorandum. This study provides an update or reaffirmation of the preauthorization plan. In this advanced engineering and design-oriented study, the hydrologic, economic, environmental, and social data are updated and a revised economic appendix to the survey report is prepared.

10. Phase II General Design Memorandum. A functional design document, heavily oriented to advanced engineering and design, is prepared as an update to the Phase I report. Data are updated as is the economic appendix to the Phase I report.

Continuing authorization studies

11. Section 205--Small Flood Control. Section 205 of the Flood Control Act of 1974 provides authority for the Secretary of the Army and the Chief of Engineers to plan, design, and construct small flood control projects not already specifically authorized by Congress. The Federal cost cannot exceed $2,000,000 for a project at a single location. A detailed flood damage analysis is required as part of the reporting procedure.

12. Section 208--Snagging and Clearing. Section 208 of the Flood Control Act of 1954, as amended, provides authority for the Corps to remove accumulated snags and other debris and to clear and straighten channels in navigable streams and their tributaries in the interest of flood control, provided the cost does not exceed $250,000 for clearing and snagging. A limited flood damage analysis is required to determine the economic feasibility of the proposed work.

13. Section 14--Emergency Streambank and Shoreline Protection. Section 14 of the Flood Control Act of 1946, as amended, provides authority for the Corps to undertake emergency construction, repair, restoration, or modification of streambank and shoreline protective works for the prevention of damage to public properties, provided the cost does not exceed $250,000. This type study involves a limited flood damage analysis.

14. Post-Disaster. In addition to these flood control studies, Post-Disaster studies are also performed by the Corps to assess

actual damages. These studies are normally conducted by field survey as soon as possible after a disaster. They provide an assessment of the disaster which can lead to a flood control study, and hydrologic, economic, and environmental data for verification of damage calculation procedures used by the Corps.

15. The studies described in the preceding paragraphs and the increased demands of new policy, such as the national economic development objectives outlined in the Principles and Standards for Planning Water and Related Land Resources and amplified in Engineer Regulation (ER) 1105-2-200, make clear that flood damage studies are an important activity throughout the Corps districts. In an effort to provide for cost reduction while at the same time maintaining increasing flood damage estimate reliability, the Office, Chief of Engineers (OCE), authorized the U. S. Army Engineer Waterways Experiment Station (WES) to perform a study to develop a working plan for establishing commonality where appropriate and for streamlining and systematizing flood damage estimation methodologies used by the Corps districts. Particular attention was to be given to the requirements and guidelines in ER 1105-2-351, "Evaluation of Beneficial Contributions to National Economic Development for Flood Plain Management Plans." This report documents the appropriate parameters of flood control project evaluation and the proposed development effort.

Purpose

16. The purpose of this study was to formulate a plan that explicitly outlines the work required to upgrade or enhance Corps capabilities to estimate monetary flood losses to various categories of property. The plan was to cover the development of systematic procedures that can be used uniformly for the different levels of detail required in various types of Corps studies, procedures that permit a rapid, straightforward analysis of flood damage for various flood control alternatives that might be employed in a given problem

situation, and procedures that permit a rapid, straightforward sensitivity analysis of flood damage calculation results.

Study Approach

17. To accomplish the purpose stated above, the work described in the following paragraphs was accomplished.

18. Literature on existing flood damage estimation methodologies and those under development, both within the Corps and other government agencies, was reviewed to identify commonality in computational procedures and data requirements. Also, literature on current data collection and data handling practices was reviewed and evaluated in regard to state-of-the-art capabilities and their applicability to future Corps needs. Appendix A contains a bibliography of information sources and materials, computer programs, and general information references. Appendix B contains more detailed information on some of the computer programs given in Appendix A. Finally, selected Corps district offices were visited and discussions were held with economics, hydraulics, and floodplain management information staffs to review current practices and to identify areas where it is possible to formulate common computation and data collection procedures and to streamline data acquisition and handling methodologies.

19. Based on the literature review and the detailed interviews, a plan of action was formulated to develop a system that will upgrade and enhance existing Corps flood damage estimation capabilities. This plan identifies how procedures will be transferred to the Corps districts for operational use. A side benefit resulting from the use of the proposed procedures will be the streamlining of the Corps division and OCE review process. This will be accomplished since all the data and procedures used in a study will be explicitly defined. The study technical adequacy can then be examined in a less time-consuming manner. The requirement for a timely review will become more important with the publishing of proposed ER 1105-2-80 which requires successive re-evaluations at intervals of five years.

Scope of the Proposed Plan of Action

20. The work plan is directed to the development of selected decision aids and computation procedures that are part of a system for use by Corps planning personnel. Specifically the work plan is directed toward streamlining and standardizing the acquisition, processing, and storage of the data needed to calculate the monetary damages to property due to waterway and coastal flooding with alternate plans for flood alleviation measures. Also included in the plan is a sensitivity analysis of the calculation results and the aggregation and reporting of results. Basic hydrologic studies completed by Corps offices to arrive at the flood surface profile and location, and the relation between flood depths and property damage, are considered only to the extent required to complete and verify the procedures for flood damage calculations. The proposed plan contains no departure from Corps concepts or general methodologies for computing flood damages. Some hydrologic and damage function development study effort will be required, however, since the precision of the flood damage estimates is directly related to the uncertainties in the hydrologic and economic data used in the estimates. Capabilities available at WES, the Institute for Water Resources (IWR), and the Hydrologic Engineering Center (HEC) will receive strong consideration in developing the final products in the proposed development program. Part II of this report briefly lists selected Corps district practices and requirements. Part III describes the development work proposed to meet the requirements. Part IV describes procedures for technology transfer, and Part V presents the proposed scheduling to accomplish the work. A schedule of the funding required for accomplishing the work can be obtained from WES.

PART II: PRESENT PRACTICES AND NEEDS

Introduction

21. The calculation of flood damages involves several activities, consisting of data gathering, data processing, data base development, damage calculations, sensitivity analysis of the damage calculations, and displaying and reporting of the results. A district economics staff normally progresses through the following steps in performing the activities in a flood damage survey.

a. Problem identification. A study is initiated usually as a result of congressional or local government requests because of recent or historical flood problems. A limited amount of investigation is performed to determine if the flood problem is isolated or regional in nature. Any impacts are briefly analyzed before a determination is made to proceed with a study.

b. Search for available data. Prior study reports, aerial photographs, soil surveys, Floodplain Information (FPI) reports, hydrologic profiles, maps, United States Geological Survey (USGS) water supply papers, and other available data are examined both to become familiar with the region and its problems and also to provide any available factual data as a basis for further analysis.

c. Available data analysis. Reaches for the aggregation of damages are generally delineated to section off regions of hydraulic similarity or homogeneous development, or to correspond to geographical or political boundaries. Floodplain boundaries are delineated on the basis of the calculated water surface profiles and gage data. The flood-impacted region is defined so that the study region can be restricted. Appropriate depth/percent damage functions are retrieved from files on prior studies or developed from available data, or real estate property surveys are planned and executed to gather the data required to develop damage functions.

d. Development of data catalog for damage analysis. The property in each reach is identified and cataloged. Field surveys are performed to supplement the available cataloged data. The depth/percent damage functions are finalized, normally with some field survey data to supplement that which is available. Each plan of improvement for alternate projects is identified as well

as the way the data must be redeveloped to describe the alternate plans. Future conditions are identified both with and without Corps project action.

e. Damage calculations. Damages are calculated and aggregated for the alternate plans for present and future conditions. A sensitivity analysis may be performed if time permits.

f. Report. The results of the survey are formalized in a report or appendix to a report.

22. Figure 1 shows the relation between the steps a district takes in conducting a flood damage survey and the activities performed in those steps. As stated in paragraph 20, this study addresses the work required to develop improved procedures for conducting flood damage surveys. For this reason, this presentation is oriented around the activities involved in an economics study, i.e. the activities identified on the right side of Figure 1. The activities are briefly introduced in this section of the report and are discussed in detail in Part III.

Data Gathering

23. Data gathering involves the process of collecting and compiling data required for damage calculations. The kinds of data required in a study depends on the type and level of detail of the study. The following is a partial list of the general classes of required data.

a. Damageable structure locations, elevations, and monetary values.

b. Damageable linear feature (i.e. roads) locations, elevations, and monetary values.

c. Damageable areally distributed property (i.e. agriculture) locations, elevations, and monetary values.

d. Relations between property loss and depth of flooding.

e. Projected flood levels for project plans for different flood repeat periods.

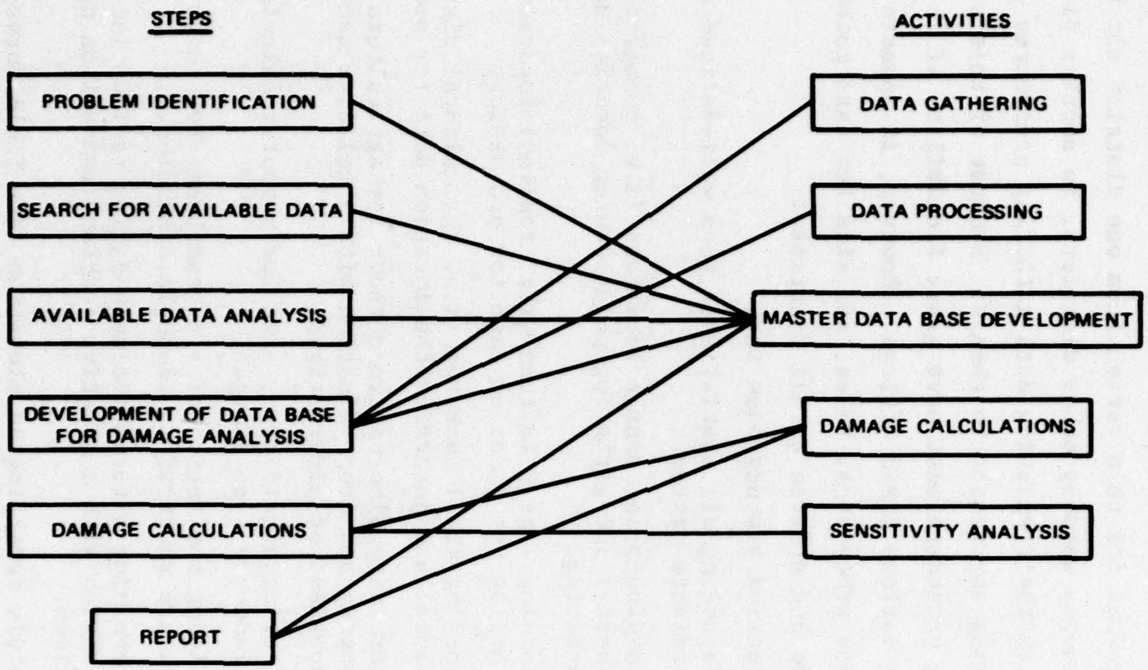

Figure 1. The relation between the activities and the steps in a flood damage survey

24. Review of the literature and conversations with District personnel revealed that several methods are being used to gather data of each class listed above. The most significant fact that emerged from the initial study was that data gathering procedures used routinely in one district could be, but are not, used to advantage in other districts. The reasons for this varied from one district not being aware of the procedures used by other districts, to another district being satisfied with their existing data gathering procedures and, therefore, not seeing any reason to change. Because of this situation, any data gathering procedure must have great flexibility if it is to be accepted by the various field offices. However, it appears that the following common procedures, rules, and aids for data gathering should be developed and offered to all districts.

a. Selecting a study base map.

b. Referencing all spatial data to a well-defined standard coordinate system.

c. Recording point source locations (i.e. commercial property) and gathering point source location data for processing.

d. Recording linear feature (i.e. roadway) locations and gathering the location data for processing.

e. Recording areal features (i.e. agricultural distributions) and gathering the location data for processing.

f. Determining alternative methods for agricultural property and crop valuation with a relative accuracy comparison of alternatives.

g. Selecting a grid array size for computer calculations of land-use type damages.

h. Defining the region of a stream basin for which economic data are required in floodplain studies.

i. Determining alternative methods for residential property valuation with a relative accuracy comparison of alternatives.

j. Rapidly recording an elevation data field survey with transit to permit an inexpensive but rigorous quality control on the survey.

k. Rapid acquisition of approximate elevation data using elevation information on available maps.

l. Rapid acquisition of approximate and accurate elevation data using information on available maps and stereo-aerial photographic data supplied by commercial firms.

m. Standard field survey data forms and procedures for use in field surveys of commercial, residential, and other point location damageable property for development of damage functions.

n. Compendium of flood water depth/percent damage relations from the Flood Insurance Administration (FIA) and selected Corps District offices and the premises on which the relations were developed.

If common procedures for the above were implemented, most of the data gathering procedures employed by the districts could be interfaced with master data files and a significant amount of manual labor eliminated in handling the data from gathering to final use in the damage calculations. Further, data can be gathered using a variety of procedures without requiring any change in the master data files or the damage calculation procedures described later in this document. Simple data formats can be defined or adapted (some are already developed for some types of data) for use in the data processing activities.

Data Processing

25. Data processing refers to the preliminary checking, the editing of the data prior to transforming into a form for inclusion in the master data base, and the final checking and editing of the data prior to insertion into the master data base. Data processing is a crucial technical area in the sense that studies are often compromised because of a lack of capability to rapidly process required, and often available, data inexpensively and present it to the users for analysis. The data processing activity is primarily a mechanical task that can be performed by automatic data processing (ADP) personnel with an assured outcome, provided proper procedures are followed. The processing procedures should be the link between data gathering

and the construction of data files used in the damage calculations. Properly designed data processing techniques can provide a measure of standardization since many subclasses of data can be processed identically. For example, the same procedures can be used for all areally distributed data irrespective of whether the data are land-use, crop type, soils, or floodplain reaches for damage aggregation. Figure 2 demonstrates the flow of data from source to master data base for a selected set of data requiring more processing than most other data required in damage calculations. Data processing, as illustrated in Figure 2, requires dedication to quality control of both the procedures used and the data handled by the user.

26. Interviews with the districts showed a lack of standardized procedures for data processing and a requirement for procedures that emphasize low processing cost, simplicity of use, multiple use procedures, and built-in quality control checks. The following data processing requirements have been identified as necessary for the various types of data handled in a normal damage calculation.

- a. A general transformation and quality control procedure for point location data.
- b. A general transformation and quality control procedure for linear data.
- c. A general transformation and quality control procedure for areal data.
- d. A general procedure for transformation of elevation data to a grid array.
- e. A series of computer programs and procedures to aid in handling water depth/percent relation data.
- f. Procedures for use in waterway and coastal cross-section data preparation.
- g. Procedures to use in formatting water surface profile data for automatic calculation of floodwater depth, damage, and boundary location on the ground.
- h. A computer program for transforming rod and transit or rod and theodolite field survey elevation data into the Cartesian coordinate system.

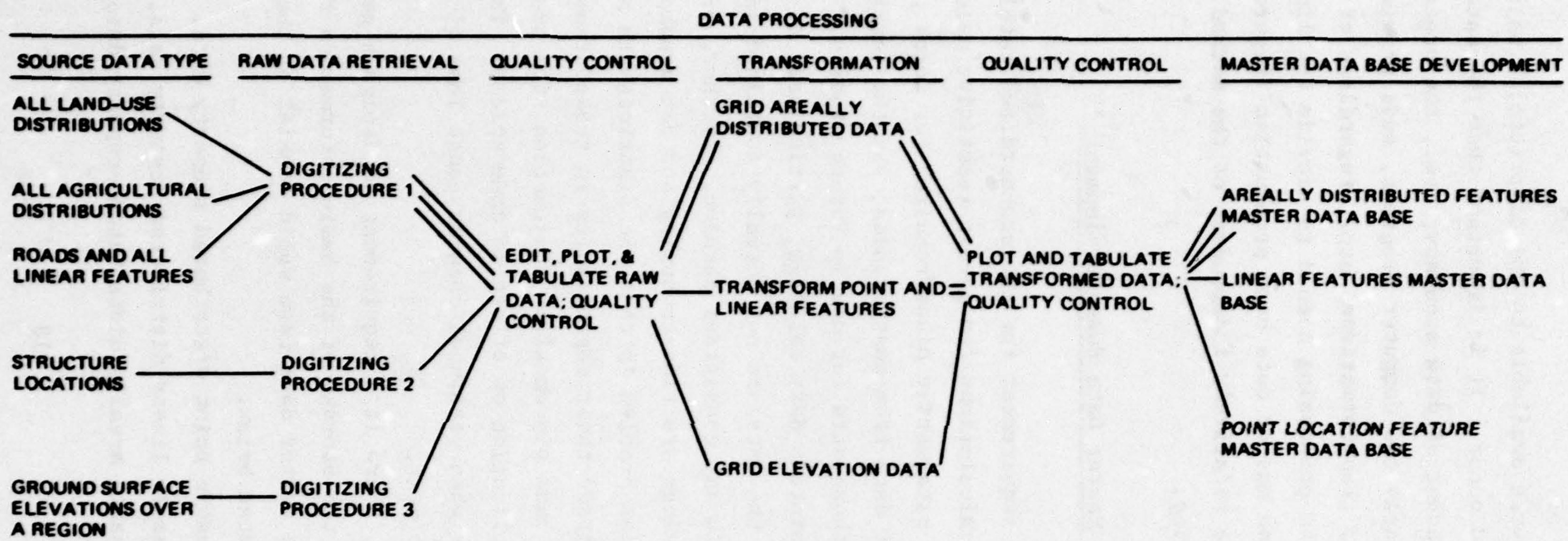

Figure 2. Data processing procedures for a sample set of data types

If these procedures were available to the districts, a major reduction in manual labor would occur. It is important that the data processing procedures be independent of data accuracy; i.e., the procedures themselves, particularly the computer programs, must provide very accurate conversions, transformations, etc., regardless of input data quality. Further, the processing needed to provide the link between raw data gathering and master data base preparation (Figure 2) must be flexible enough to be relatively independent of the method used in the data gathering activity.

Master Data Base Development

27. There is a requirement for the standardized cataloging of data used in damage calculations (to permit repetitive calculations to be performed for the alternative plans required for Corps projects), the easy retention of data from past studies, and the retrieval of selected subsets of those data for use in future studies. All district economics branches maintain data catalogs, particularly of damage functions. However, the data are not normally contained in any standard format, or reported in any consistent fashion. Further, procedures for updating the catalogs are time-consuming and not accomplished on a routine basis. A major problem is that the districts are not funded to standardize or upgrade their capabilities in these areas, and any improvements must be made piecemeal in conjunction with projects. For this reason, much duplication of effort is commonplace. This problem is compounded further when personnel changes cause loss of continuity from one study to the next.

28. In general, there is a requirement to design a general master data base for the storage of the basic information required for damage analysis. The master data base would consist of the series of master data files listed below.

a. Damageable point distributed property data.

b. Damageable linear distributed property data.

c. Damageable areally distributed property data.

d. Damage functions.

e. Flood location and elevation data.

f. Ground location and elevation data.

In addition to the master data base design, there is a requirement for simple procedures for insertion of processed data into the files and for editing and updating the files.

29. The master data base should be developed as a general data base with a capability to accept all types of data required for different types of damage calculations. There must be flexibility, however, in the sense that any one Corps study normally involves one type of damage calculation, so that the total capabilities of the data would not be exercised on any one project. The amount of data stored in the data base for any one project would, therefore, be a small subset of what could be handled, and only those required data would have to be gathered and processed.

Damage Calculations

30. All district offices presently have a damage calculation capability. Few offices, however, appear to have had an opportunity to develop procedures to the extent that they can be used to reduce manual labor to the extent possible. That is, automated procedures have been developed to offer help on some of the labor intensive operations, but there does not appear to be any set of procedures constructed to aid the total effort in a systematic fashion.

31. Almost all available automatic procedures studied appear to have been developed for structure-by-structure damage calculations. This is reasonable, since in many districts the level of public concern and the potential financial flood loss to commercial and residential properties significantly outweigh considerations for other type properties. The procedures are sometimes extended for use in urban land-use type calculations when it is convenient to do so.

32. In addition, calculations are performed in either a "reference point" or "zonal" fashion. A major reason for choosing between the procedures is that each aids in reducing manual labor for a different type aggregation of damages, the zonal method for zonal aggregation and the reference point for reach aggregation. Either method can be used if necessary, however, for either aggregation scheme. Both methods appear to require the same degree of labor in preparing for calculations.

33. All of the interviewed personnel consistently expressed a need for quality control at intermediate steps in a damage calculation. All felt that this was necessary since as the work advances, the damages become more aggregated for reporting purposes and it becomes impossible to apply even common sense approximations to the damage estimates for a validity check. The concern stems from experiences with erroneous data that remain undetected until the final stages of calculation. It is possible to apply quality controls to the data used in the calculations to search out inconsistencies between the available raw data and what is tabulated for use, but some errors caused by the lack of raw data are very difficult to detect with existing procedures. Each of the districts expressed a concern over the inability of recently developed automatic procedures to meet this requirement for intermediate reporting and pointed this out as one major stumbling block to program acceptance at the working level.

34. In general, the computer procedures developed in the districts do not approach the state of the art. Parts of the set of steps performed in the total operation are aided by computer programs that are, for the most part, not well documented, somewhat cumbersome on input, and scanty on report explanation. In short, the procedures can be used only by "insiders," and there may not be many "insiders" who actually operate the programs and understand what is happening. In addition, many of the procedures betray their birth as substitutes for manual work steps. The manner in which work is performed is often tailored to the capabilities of the available equipment. In the same

way, most available computer programs appear to be automatic versions of manual calculations that were developed in a particular manner because of limitations on manual labor, even though the limitations have been removed by the use of computer equipment.

35. There is a requirement for development of new or adaptation of selected available damage calculation procedures as part of a system for damage calculations. The system should be capable of performing calculations in the same ways currently used by the districts so that a radical departure is not made from current work procedures and no departure is made from accepted Corps technical methodologies. The developed procedure should, however, also have a capability for performing calculations in a manner consistent with modern equipment capabilities and increasing new requirements placed on the districts. A major consideration should be the ability to produce reports of interim calculation results at any stage during the total calculation process so that a level of quality control can be exerted that only the economics staff can accomplish.

Sensitivity Analysis

36. A sensitivity analysis is a study of the change in calculation results as a function of variation in the values of the parameters used in the calculation. In the course of a Corps flood analysis, data are refined and results are sometimes repetitively calculated several times before the staff is satisfied with the quality of the results. An indication of the sensitivity of the results to data variation can sometimes be gained in such an exercise, but does not constitute an efficient way to conduct a sensitivity analysis since no systematic approach is used. The Corps districts do not routinely perform sensitivity analyses on studies primarily because of the lack of proper technical tools and time. The calculation portion of a sensitivity analysis can be a very straightforward repetitive calculation if the data processing procedures are set up in a systematic fashion.

37. Sensitivity analysis is a necessity for the proper design of a study and for performing any quantitative assessment of study result accuracy. For example, a sensitivity analysis can be used for an error analysis by estimating the error in each of the parameters used in the damage calculation and repetitively calculating the estimated damages while varying the parameter values over the range of error using present procedures. Present terminology used in reporting damages need not be changed; the calculations still yield "estimated damages." It is not obvious how errors in the data influence the calculation results except in studies involving very simple conditions. It is entirely possible that a good error analysis would demonstrate that errors tend to cancel out, that the value normally calculated is close to the mean, and that the analysis distribution is highly clustered.

38. There has been an increasing emphasis within the Corps over the past few years on refinement of the data used in the damage calculations, particularly commercial and residential data. The cost of gathering the data is becoming prohibitive. Generally, districts do not gather refined data in a program dedicated only to that purpose at less than a ten-year interval because of the cost. No quantitative data were identified which demonstrated how detailed the economic data should be. Such a demonstration must be founded on a sensitivity analysis in which the first step consists of deciding what the desired accuracy is to be, then performing an analysis to determine the quality of input data needed to meet the output requirements.

39. In summary, a sensitivity analysis is a particularly powerful tool for gaining quantitative information on the quality of a damage calculation and could provide Corps staff with insight as to the relative importance of various required data.

PART III: PROPOSED SYSTEM DESCRIPTION

Introduction

40. The procedures described in this part of the plan will be developed to aid the District office personnel in the performance of the activities shown on the right side of Figure 1. The left side displays the steps involved in a damage survey while those procedures that will be developed are grouped under the "activities" heading shown on the right side of Figure 1 and are discussed in the following sections. The master data base is intended to provide a catalog of information from past studies that could aid in future flood damage studies. The master data base provides the vehicle for storage of data in a standard fashion so that available data can be analyzed rapidly for applicability to a new study. Some procedures will be developed for gathering data for the required data base from both available source materials and field surveys. Data processing procedures will be developed for checking, editing, displaying, and transforming the data in a simple, consistent manner for building the data base required for calculations. More emphasis in the plan is placed on some activities than on others, and no attempt is made to cover an activity in a totally comprehensive manner. Rather, emphasis is placed on providing tools for much of the "mechanical" work performed in the calculation of damages in order to give district personnel more freedom to examine the adequacy of technical results of their flood damage estimates for better quality control. The procedures are oriented to the use of a computer as the most effective tool which permits the flexibility and multiple calculation (for alternate plans) capability required in present-day planning activities. Emphasis will be placed on calculation procedure flexibility without loss of calculation rigor. Further calculation efficiency will be stressed to provide a capability to rapidly test multiple hypotheses quantitatively. A degree of standardization will be necessary to provide the ability to transfer data and procedures from district office to district

office with minimum labor. Each district has unique problems which will warrant tailoring of the procedures to fit its needs. The handling of unique problems is normally performed in the calculational procedure by adjustment of data, emphasis on specific types of damages, and the separate reporting of certain types of damages. The proposed procedure is intended to provide a capability to handle unique problems within the standard procedure.

41. The central part of the proposed plan is the development of a consistent but flexible procedure to calculate damages. Comparable procedures for use in gathering, processing, and storing the data required for damage calculations will also be developed. Still other procedures will be developed to provide rapid methods for performing a sensitivity analysis and for displaying and reporting the data used in, and the results of, calculations. Figure 3 illustrates, in a simple schematic fashion, the steps in a damage survey study using the procedures advocated for development in this report.

42. The flow of work shown in Figure 3 employs procedures similar to those presently used by the districts. It is emphasized that computational efficiency can only result if the procedures used are viewed as part of a system; i.e., the procedures are interconnected to impart a standardized, internally consistent flow to the work of a damage survey.

Data Gathering

43. The general classes of data required for flood damage studies were listed in paragraph 23. This section describes a selected set of procedures and aids that are advocated for development to standardize and speed up the data gathering process without compromise of accuracy. The data gathering procedures and aids are designed to interface with the master data base and to reduce manual labor in handling the data between gathering and final use in the damage calculations. However, great flexibility is permitted in the data gathering process without requiring <u>any</u> change in the master data base or the damage calculation

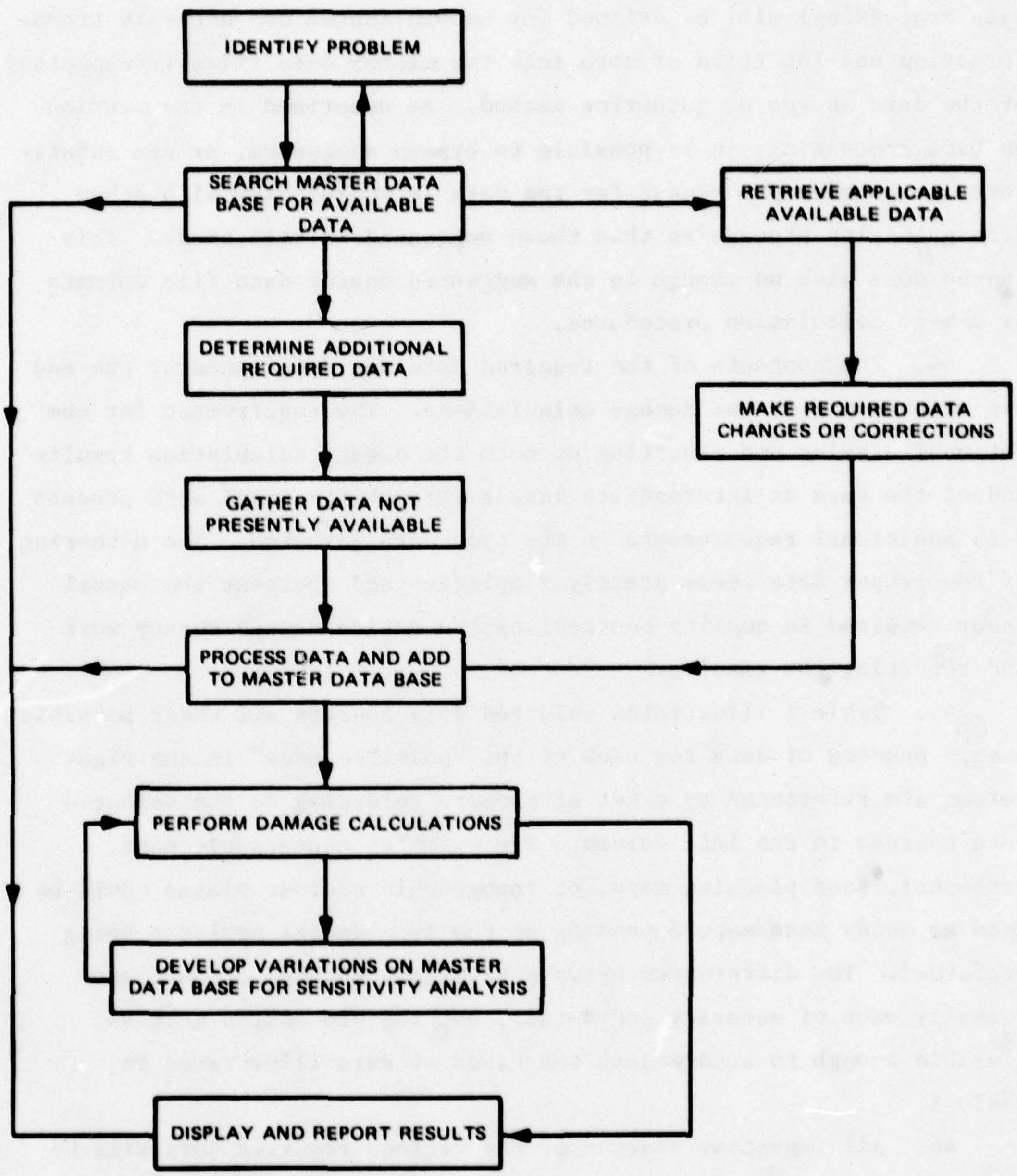

Figure 3. Scheme of how procedures are used in a damage survey study

procedures described later in this plan. Simple data formats which are required in the data processing activities (see the section on Data Processing) will be defined for uncomplicated and accurate transformation and insertion of data into the master data files irrespective of the data source or gathering method. As described in the section on Data Processing, it is possible to bypass suggested, or use substitute, processing procedures for the data in conjunction with other data gathering procedures than those suggested in this study. This can be done with no change in the suggested master data file formats or damage calculation procedures.

44. The contents of the required data are determined by the end use of the data in the damage calculations. The requirement for the rational display and reporting of both the damage calculation results and of the data at intermediate levels through the total work process sets additional requirements on the type data gathered. The gathering of the proper data items greatly simplifies and shortens the manual labor required in quality controlling the entire damage survey work and reporting the results.

45. Table 1 illustrates selected data sources and their possible uses. Sources of data for each of the "possible uses" in the right column are referenced by a set of numbers referring to the selected data sources in the left column. For example, topographic maps, orthophoto base planning maps, or topographic contour plates could be used as study base maps depending on the type damage analysis being performed. The differences between alternate sources of data are normally ones of accuracy and detail, but the procedures must be flexible enough to accommodate the kinds of data illustrated in Table 1.

46. All important sources of the various required data will be identified in the proposed development effort in terms of the data accuracy that can be achieved and the limitations on the data from that source. Specific examples of data used by various Corps districts in flood damage studies will be used in the proposed study to illustrate

the sources. One or more procedures for data acquisition from each source will be listed and formats which are most convenient for processing and input to the master data base will be identified. Available validated procedures will be used where possible. Recommendations for use of identified data gathering procedures and data sources will be based on the amount of manual labor reduction, increase in accuracy, and required development effort to fully implement the procedures in the general system.

47. A brief description of the work involved to develop the data gathering aids listed in paragraph 24 follows:

a. Selecting a study base map. The choice of a specific base map significantly influences the type and amount of manual labor expended throughout a flood damage study. The purpose of a base map will be described. Various base map alternatives will be described with respect to the relative accuracy with which data can be gathered from and displayed. The effects of choosing different type maps will be described.

b. Referencing all spatial data to a well-defined standard coordinate system. A standard coordinate system will be advocated for use in the referencing of all spatial data. The advantages of using such a system will be shown. Rules will be given for referencing data to the system.

c. Recording point source locations (i.e. commercial property) and gathering point source location data for processing. A general format will be developed for recording point source data. The format will be developed with simplicity and flexibility as primary objectives. Two procedures, one for low and the other for high data volume usage, will be described for gathering the point source data; examples of the procedures will be illustrated. The procedures will be useful for both subsequent manual data processing and cataloging or computer processing and storage in data files.

d. Recording linear feature (i.e. roadways) locations and gathering the location data for processing. A general format will be developed with simplicity and flexibility as primary objectives. Two procedures, one for low and the other for high data volume usage, will be described for gathering the linear data; examples of the procedures will be illustrated. The procedures and formats

will be directed primarily toward subsequent computer data processing, although they will be useful for manual processing and cataloging in some circumstances.

e. Recording areal features (i.e. agricultural land-use distributions) and gathering the location data for processing. A general format and two procedures will be developed as for (c) above. The procedures and formats will be directed toward subsequent computer processing. The "low data volume" procedure will be intended for use with data file updating and editing procedures, while the "high data volume" procedure will be intended for all applications.

f. Determining alternative methods for agricultural property and crop valuation with a relative accuracy comparison of alternatives. Procedures developed under IWR auspices and those in use in selected Corps districts will be reviewed and presented with the concurrence and comments of the procedure users. The relative accuracies of the procedures will be described to the degree possible as well as relative advantages and disadvantages.

g. Selecting a data grid array size for computer calculations of land-use type damages. When land-use type damage calculations are performed, the results are a function of the spatial resolution (i.e. the grid size). The relationship between grid size and final damage calculation results, as a function of land-use delineation detail and classes, will be described in a straightforward manner, and rules will be indicated for choosing a grid size for a specific flood damage calculation. Examples of the grid size effect on final damage calculation results will be given.

h. Defining the region of a basin for which economic data are required in floodplain studies. A guide, most applicable to rapidly developing areas or areas not previously studied in detail, will be given for estimating the amount of economic field team survey to be performed through a delineation of the regions to be surveyed. The guide is intended to aid the scheduling of the field collection effort very early in a flood damage study and to avoid over- or under-sampling.

i. Determining alternative methods for residential property valuation with a relative accuracy comparison of alternatives. Procedures developed under IWR auspices and those in use in selected Corps districts will be reviewed and presented with the concurrence and comments of the procedure users. The relative accuracies of the procedures will be described to the degree possible as well as relative advantages and disadvantages.

j. Rapidly recording an elevation data field survey with theodolite or transit to permit an inexpensive but rigorous quality control on the survey. Procedures will be described and a format presented for survey data recording in the field. The format will be useful with normal field survey procedures. The format is intended for direct input to the computer for a very rapid and inexpensive transformation of the survey data and rigorous quality control.

k. Rapid acquisition of approximate elevation data using elevation information on available maps. Procedures will be described for office use in rapidly gathering approximate elevation data, especially point locations and cross sections, from available maps. The procedures will be amenable for use with different scales and types of maps; rules will be given for maintaining data consistency when gathering data from maps of the same region that are not spatially consistent (a situation that occurs almost 100 percent of the time).

l. Rapid acquisition of approximate or accurate elevation data using information on available maps and stereo-aerial photographic data supplied by commercial firms. The objective is to provide a straightforward procedure for reducing field survey manual labor by providing elevation data for use as cross sections, elevation control for structures first floor elevation measurements, and general purpose ground control. Since equipment to be used in conjunction with the stereo-photographs is more likely found in an architect engineer (AE) firm, a sample set of contract specifications for the required aerial photographs will be provided. A measure of vertical elevation accuracy as a function of aerial photograph scale and flight altitude will be provided for use in preparing the flight contract specifications. Procedures will be described for the preparation of materials to be given to, and the work to be required of, the AE firm for furnishing the three types of elevation data identified above from aerial photography.

m. Standard field survey data forms for use in field surveys of commercial, residential, and other point location damageable property for construction of damage functions. Forms developed under IWR auspices and those in use with Corps districts will be reviewed for applicability; general forms will be developed, the object of which will be standardization and completeness. The use of data items on the form will be at the option of the individual district's need to correspond

with local requirements. Those data items necessary for use of the data processing and damage calculation and display systems proposed in this study will be noted.

n. Compendium of flood water depth/percent damage relations from the FIA and selected Corps district offices and the premises on which the functions were developed. The damage functions will be tabulated in a document and placed in computer data files. The computer data files will be in the standard format developed for the master data base described in paragraphs 80-83. The object will be to provide ready access to functions for which much development time and energy has already been spent. Districts can compare these with their own damage functions as part of a sensitivity analysis or use some of these in place of theirs. The functions in the compendium could, also be used as part of the sensitivity analysis for district studies.

Data Processing

48. As emphasized in paragraph 26, simple procedures that provide inexpensive processing are needed by the districts. Further, multiple use and built-in quality control are important aspects of the proposed procedures described in this section. These objectives, which are vital to a standardization of procedures, are further developed in the following paragraphs.

Low processing cost

49. Processing cost involves the total cost of computer operations, constraints on computer use, and manual labor involved in preparing data within the processing procedure. All computer programs will be developed or adjusted to operate on small memory machines and will be made independent of the input data set size. Some of the programs are available now for use on small computers and have been thoroughly tested. This goal can be anticipated even for computer programs that handle massive data files on the order of 10,000 or more entries. The manual labor portion of the cost is directly related to the simplicity of the procedure. Simple procedures imply reduced cost in training personnel and the ability to use less expensive personnel

for the same type work. Although several different computer programs performing different types of operations are involved in data processing, the computer costs for most types of data processing are negligible compared to data collection and quality control costs.

Simplicity of procedures

50. The procedures will be developed so that manual operations will be used only when necessary during data processing. For example, all input data formats developed in the data gathering activity will contain space for all required data, some of which are optional depending on the type and level of accuracy of damage calculation to be performed. However, the data processing procedures will be developed to automatically quality control all input data to provide a full range of edit messages and references to data known or suspected to be erroneous by the computer programs. The procedure user will input all required operator decision data during the initial data processing stage, and those data will be automatically carried through the processing phase so that operator-induced errors will be minimized in what is essentially a mechanical process.

Multiple-use procedures

51. Although the number of different classes and subclasses of data and data sources is large, the data can be grouped into a limited number of data format categories. For example, the present and all future land-use alternatives and all agricultural data are areally distributed data, and, therefore, are amenable to processing with identical procedures, thus avoiding the confusion and labor engendered by individual computer programs for every subitem of data. Figure 2 illustrates the multiple-use process for a sample set of data types. Any computer program serving multiple uses must be designed to keep track of the type data it is operating on, automatically perform all quality control checks pertinent to that type data, and output the results in a form and format consistent with the requirements of subsequent computer programs so that manual intervention is unnecessary.

Data quality control

52. Processing quality control will be accomplished by providing for three types of quality checks on the data.

a. Reduction of manual intervention. All data processing procedures between data gathering and insertion into the master data base will be designed to require manual intervention only at the data gathering level where all data are prepared for a given data set at one time. The very common problem of a requirement for multiple input of data between processing operations will be avoided with the attendant confusion and possibility of erroneous data input.

b. Multiple and overlapping checks. All data processing procedures will include multiple overlapping checks of internal data consistency and adequacy. Flexibility in data processing is mandatory because different types of data are required depending on the type damage calculation to be performed. Capabilities to perform routine adequacy checks will be built into the procedures to ensure that sufficient data types are input to perform a damage calculation.

c. Visual aids. The ability to present simple and inexpensive graphic and tabular intermediate outputs of the data (Figure 2) to the user will be developed as an integral part of the system. The data will be presented to the user in such a manner that the user's mechanical labor is minimized. For example, all graphic presentations of spatially distributed raw data include a computer-plotted overlay at the identical scale of the data sources.

53. The emphasis on quality control ensures that the data the computer has on file are exactly those which the user thinks the computer has and that sufficient data are available for damage calculations. The importance of stringent quality control during processing cannot be overemphasized. Once erroneous data get past the data processing stage, they will probably not be discovered until final damage calculations are performed. The cost of "data refinement" at that stage can become both embarrassing and expensive.

54. The data processing procedures to be developed (i.e. those described in paragraph 26) or adapted in the proposed study are listed

and described briefly below. A synopsis of items a-b below is shown as Figure 4.

a. A general data transformation and quality control procedure for point location data. The procedure will consist of two computer programs, instructions for quality controlling the data by examining the output of the computer programs, and instructions for editing errors in the raw data. The computer program DIGEDIT will produce a graphic product in the form of a computer plot that is an exact overlay of the original map from which the data were gathered and a tabular listing of the data as a legend for the overlay. The computer program PNTLIN will be developed to perform an in-depth check of the internal consistency of the raw data, transform it into the Universal Transverse Mercator (UTM) coordinate system, and output both graphic and tabular summaries of the transformed data for visual inspection. The transformation will include a rectification of spatially distorted data.

b. A general transformation and quality control procedure for linear data. The procedures will have identical capabilities to those listed in a above.

c. A general transformation and quality control procedure for areal data. The procedures will have identical capabilities to those listed in a above, except the computer program FACGRD rather than PNTLIN will be used for data transformation, as shown in Figure 4.

d. A general procedure for transformation of elevation data to a grid array. The procedures will have identical capabilities to those listed for a above, except the computer program ELEVGRD rather than PNTLIN will be used for data transformation as shown in Figure 4. The graphic output of ELEVGRD used for quality control will be a computer-plotted contour map of the transformed data at a contour interval selected by the user.

e. A series of computer programs and procedures to aid in handling depth/percent damage relation data. The series of aids will provide capabilities to perform the following calculations and provide output displays for quality control checks.

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* The Universal Transverse Mercator (UTM) coordinate system will most probably be advocated for use as a general coordinate system.

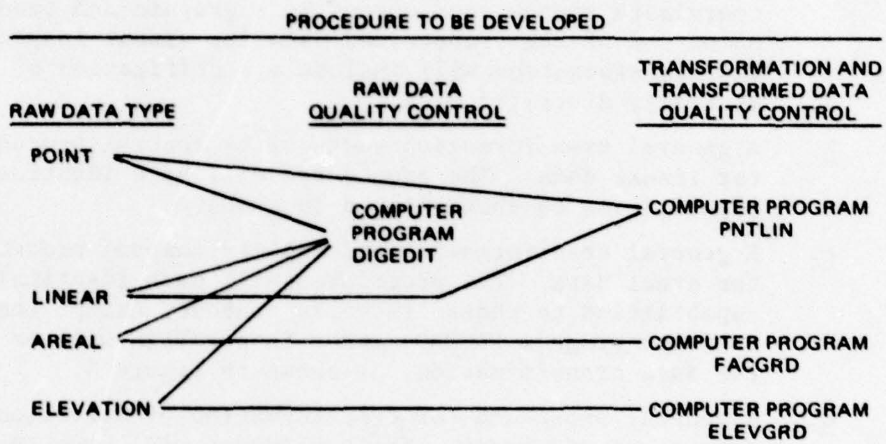

Figure 4. Synopsis of the procedures to be developed for point, linear, and areally distributed data and elevation data

(1) Transformation to analytic function description. The object is to provide an analytic function description of a set of depth/percent damage data. A series of common analytic functions, including a polynomial expansion, will be provided in a computer program which will fit the data by analytic function coefficient adjustment. The program, as an option, will plot the fitted function(s) and raw data points for visual inspection.

(2) Transformation to series-of-points description. A computer program will be developed to accept a depth/percent damage curve as a series of points and produce an equivalent description of the curve as a second series of points. The operator will be able to specify sets of values in depth or damage as the basis for the transformation so that the format can agree with current individual district practices. The program will also output, as an option, a graph of the original and calculated series of points. The new series of points will be calculated based on a sliding local exact quadrature fit to the original input data.

(3) Compilation of an *aggregate damage function*. All land-use type damage calculations are performed with aggregate damage functions. A computer program will be developed to construct an aggregate from single functions. The user will select any number of functions to be included in the aggregate and attach a weight to each function. The computer program will build the new function from the old functions and provide all capabilities given in (1) and (2) above. Input of the single function will be by direct input of the curves as a series of points or by identification of the functions in the damage functions master data file described later in the proposed study.

(4) Compilation of mean value functions from damage survey. A computer program will be adapted from a standard statistical package for calculation of a damage function from field data points. The calculation procedure will be a root-mean-square best fit. A computer-plotted graph will be produced to display the input data and the calculated curve.

f. Procedures for use in waterway and coastal cross-section data preparation. The location of cross sections used in backwater (or the equivalent for coastal areas) calculations are a required type of data

for a very rapid automatic calculation of damages and floodwater location. Procedures will be described for transforming the gathered data into a form and format to be used in the damage calculation.

g. Procedures to use in formatting water surface profile data for automatic calculation of floodwater depth, damage, and location on the ground. The water surface profiles for alternate plans, storm repeat periods, and present and future conditions are required for damage calculations. A very rapid automatic damage calculation and floodwater location can be performed for all combinations of flood conditions when the required data are properly prepared. Instructions for preparing the data from water surface profiles in conjunction with the cross-section data, a very straightforward task once the cross-section data are organized, will be given.

h. A computer program for transforming rod and transit or rod and theodolite field survey elevation data into the Cartesian coordinate system. A computer program will be adapted for transformation of field survey XY or XYZ data into a usable coordinate system. The program will accept the input data directly in the field collection format (see paragraph 47j) and calculate the output data at the user's option either in feet or metres relative to the baseline or in UTM coordinates. The output will be produced in a tabular format with magnetic disk and punch cards as optional output media with a user-specified format. The program will also produce a computer plot of both plan and profile views of the data.

Master Data Base Development

55. A master data base consisting of a series of master data files will be developed for storage of the basic information required for damage analysis. The master data files are listed below.

a. Damageable point distributed property.

b. Damageable linear distributed property.

c. Damageable areally distributed property.

d. Damage function.

e. Flood location and elevation.

f. Ground location and elevation.

56. The master data files will be the central repositories of data to be used in all levels of damage analysis studies. A specific damage analysis by a district may not require the use of all data files either because of the type damages being considered or the manner in which the analysis is performed. For example, a consideration of only residential damages would not require the use of the damageable linear or areally distributed property data files. An analysis in which reference points are used in each reach would not require the use of the flood location and elevation or the ground location and elevation data files which are used in alternate, more accurate, procedures to accomplish the same goal as choosing reference points. The data base files will be designed to efficiently accommodate all such situations. For example, the data files will be designed to contain space for all data required for damage analysis and to interface in format and content with the data gathering and processing procedures on input and with the damage calculation procedures on output, as shown schematically in Figure 5.

57. Although space will be allotted in the data files for the data required for all levels of damage analysis, it is not necessary that all spaces be filled in order to make the data useful for damage calculations. Only those data required for the type damage analysis being performed, as described in paragraphs 115-121 need be present. In addition, the ability to store only the actual data placed in the file will be incorporated into the system so that the amount of storage space required will be minimized. Long-term storage of the data will be provided through use of magnetic tape. For example, at the completion of a study, a magnetic tape copy of the complete data base used in the study would be prepared and stored with other records from the study. This would enable district personnel to very rapidly retrieve and review at a later date the exact data used. The magnetic tape offers a neat, convenient, inexpensive way to retain the <u>exact</u> data used in a project for future reference. The standardized format will permit the identification of all data internal to the data files and

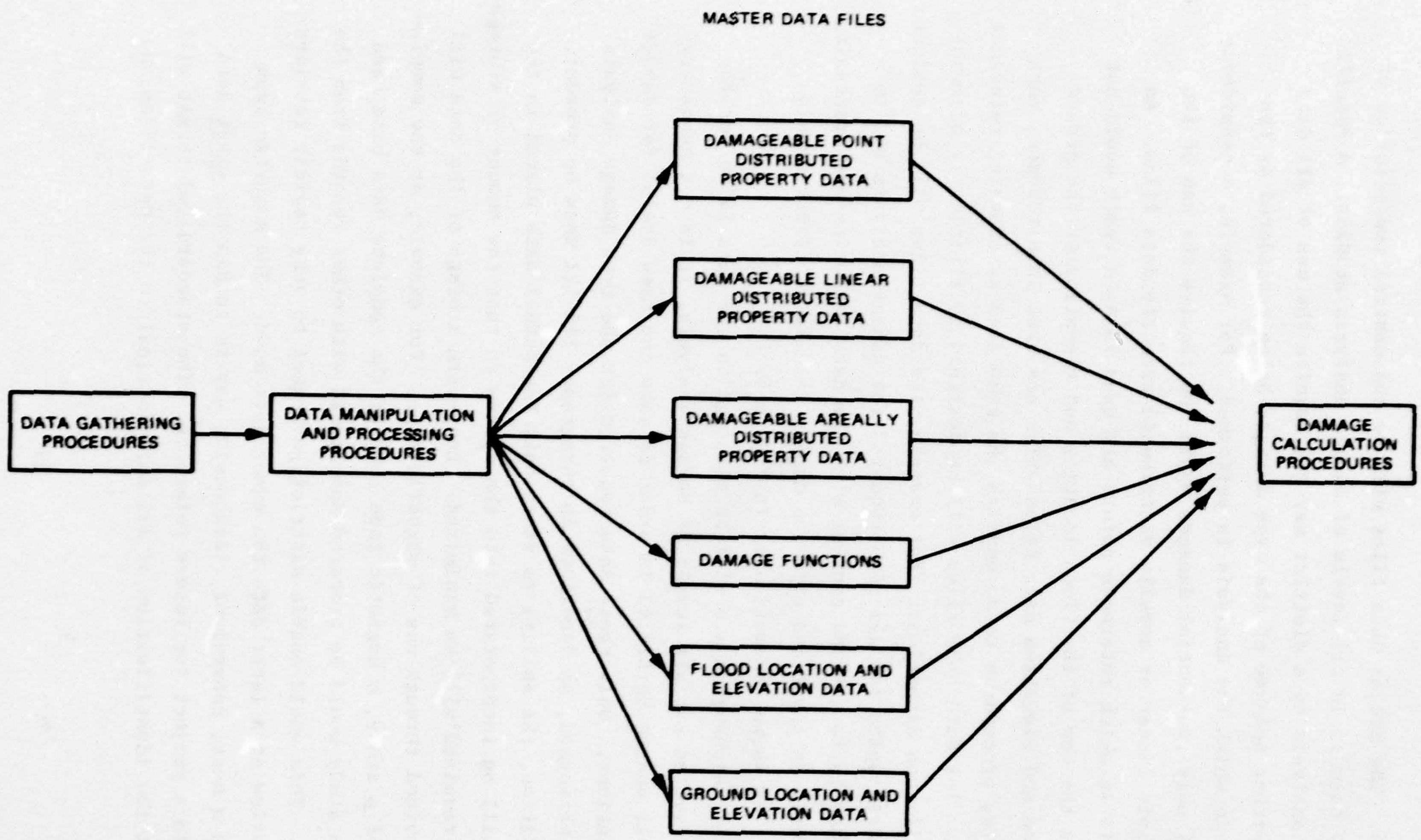

Figure 5. Schema of relation between the master data files and input to and output from the files

the use of general procedures for retrieval of specific data from a file on request. Details are therefore not lost even if there are personnel changeovers.

58. Procedures will be developed for inserting the processed data into the master data files. The procedures will be straightforward and require a minimum of human intervention since the file formats and processed data formats will be set.

59. Procedures will be developed for displaying and reporting the contents of the master data files. The reports are intended both for internal study team use and for inclusion in the flood damage study reports. The displays and reports provide an inexpensive way to quality control the contents of the master data files.

60. In summary, the proposed work to be performed involves the development of the master data file formats, procedures for entering data into the master files, and procedures for editing the data files. Development of the formats will require close coordination with several district offices to ensure that the development is complete. Each of the master data base items is described in the following paragraphs.

Damageable point distributed property data

61. This file will contain data on all damageable property assigned to a single geographic location. The property, consisting of both structures and contents, will be classed as follows in order to comply with district report requirements, particularly those as set forth in ER 1105-2-351.

- a. Industrial. Properties on which industrial or manufacturing output is generated.
- b. Commercial. Properties used in the handling of industrial output goods or services to the general public. Structures used for retail, wholesale, distribution, warehousing, etc., are included as well as offices, professional buildings, and shopping centers.

c. Residential. Properties including all single and multi-family residences, whether owned by residents individually or cooperatively, corporations, government agencies, or landlords.

d. Public. Property owned by the public jurisdiction, including civic centers, court houses, schools, military base structures, park facility structures, bridges, government offices, water treatment plants, etc.

e. Semipublic. Property open to membership and not owned by the public jurisdiction, including churches, temples, clubhouses, etc.

f. Recreational. Structure properties used for public recreation.

g. Agricultural. Non-crop structure properties used in agricultural production, including silos, feedlots, barns, shelters, etc.

62. Each of these classes will be subdivided into subclasses. The differences between subclasses will be based on the requirements for different depth/damage functions required for each subclass structure. For example, the damage functions for slab-on-ground and basement foundation construction of single family residential structures are significantly different. The preliminary subclasses of the residential class are single family and multiple family. A further (preliminary) subdivision of these subclasses is as follows.

Class: Residential

Subclass: Single Family	Subclass: Multiple Family
Mobile home	Split level
Split level	Single story with basement
Single story with basement	Single story without basement
Single story without basement	Multiple story (for each family) with basement
Multiple story with basement	Multiple story (for each family) without basement
Multiple story without basement	Multiple story (with single family dwelling on single floor)

Subclasses of the other point damageable property classes will be developed within the proposed study.

63. Space for data items such as those listed below will be allotted in the master data file for each damageable property.

class	depth/percent damage curve
subclass	ground elevation
location	first floor elevation
waterway	elevation relative to reference position
basin	structure value
subbasin	contents value
reach	value date
update date	

64. Brief definitions of the data items listed in paragraph 63 are as follows.

a. Class. The category, set forth in ER 1105-2-351 (paragraph 61), in which the property is listed.

b. Subclass. Subcategories of the class categories defined for each category. The subclasses are defined to contain properties that have similar depth/damage functions.

c. Location. The UTM coordinates and the UTM zone will be used. The use of UTM coordinates is the simplest and most accurate method for structure location and for automatic computer retrieval from the master data files. It also permits the use of a simpler and more accurate method than the use of "reference position" for calculating elevation at the structure location and for automatically aggregating damages by regions specified by coordinates.

d. Waterway. The waterway that is expected to cause flooding of the property.

e. Basin. The river basin in which the property is located.

f. Subbasin. The subbasin in which the property is located.

g. Reach. The reach in which the property is located.

h. Update date. The last date on which the data were reviewed and edited or updated.

i. Depth/percent damage curve. A reference to the specific depth/percent damage curve to be used for this property in a damage calculation.

j. Ground elevation. The elevation of the ground, to at least the nearest one half foot (0.1 m), at the structure where the first floor elevation is measured.

k. First floor elevation. The elevation of the structure where flooding first occurred.

l. Elevation relative to reference position. The difference in elevation between the first floor and reach reference position (used in reference position type damage calculations).

m. Structure value. The value of the structure at the value date on record.

n. Contents value. The value of the structure contents at the date on record.

o. Value date. The date for which the structure and contents are valued.

Damageable linear distributed property data

65. This file will contain data on all damageable property having a linear structure, such as roads. The property will be classed as described in paragraph 61. The major subclass related to linear features is roads. Other subclasses are electric power lines and sewage pipelines. Each of the properties will be placed in a sub-subclass, based on a requirement to report damages and to apply damage functions by sub-subclass. A preliminary list of sub-subclasses for roads is as follows:

divided highway	hard-surface road
undivided highway	secondary road
	trail

66. Subclasses and sub-subclasses for the other property classes will be developed as necessary within the proposed study.

67. Space for the following data will be allotted in the master data file for each damageable linear property in the public class. Similar data sets will be defined for each of the other property classes in the proposed program.

class	stage/percent damage curve
subclass	structure elevation
location	elevation relative to reference position
waterway	
basin	value
subbasin	value date
reach	
update date	

68. All of the data items have the same meanings as the data items listed in paragraphs 61 and 64 except for the following:

a. Location. A string of UTM coordinates defining the structure location.

b. Structure elevation. The elevation of the damageable property (i.e. road) at each of the locations specified in the data item "location."

c. Elevation relative to reference position. The difference in elevation between the structure surface and the reference position at each of the locations specified in the data item "location."

d. Value. The per-unit-length "value" of the structure.

Damageable areally distributed property data

69. This file, stored on magnetic tape in the format shown in Figure 6, will contain data on all damageable property that has an areal distribution. The property will be classed as shown in paragraph 61. The definitions of the classes and data items are as shown in paragraphs 61 and 64, respectively, except for the following expansions of those definitions.

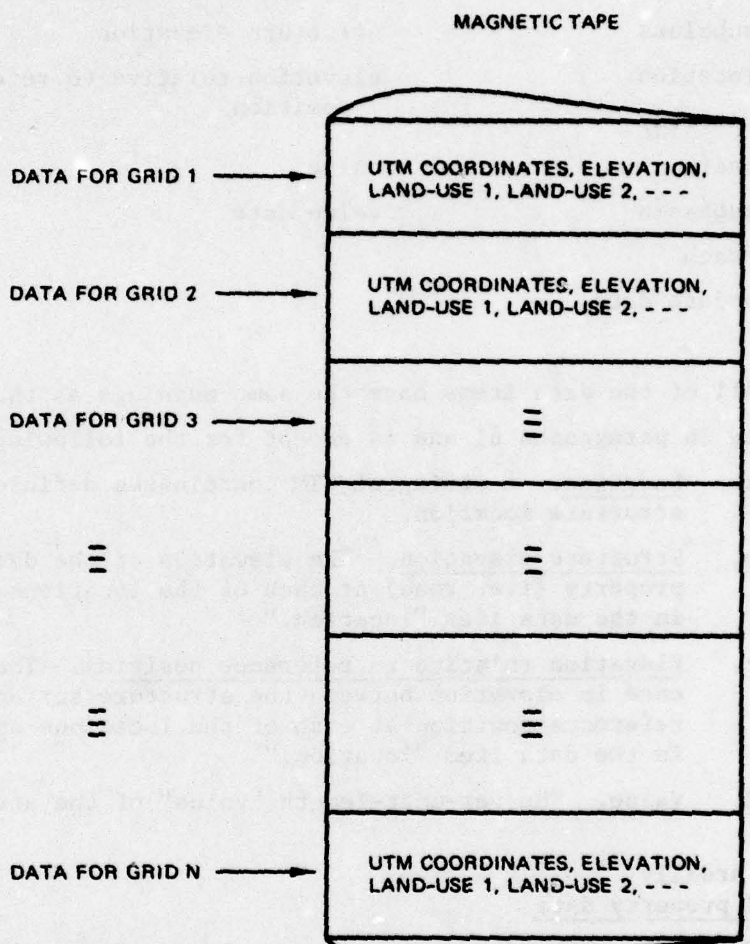

Figure 6. Grid data stored on magnetic tape

a. Public. The property will include parks, educational institution grounds, etc.

b. Recreational. The property will include recreational grounds.

c. Agricultural. The property will include all lands contributing to agricultural income.

70. As stated, it will be possible to calculate damages on a structure-by-structure (Point Damageable Property Data), length of property (Linear Damageable Property Data), or areal basis (Areal Damageable Property Data). Damages to some types of properties, particularly crop farmland, can be calculated only on an areal basis, while other properties can be calculated on either a structure-by-structure or areal basis. It will be possible to maintain these same data, in different formats, in both this and the other property data files as required for calculations.

71. Each of the classes listed in paragraph 61 will be further subdivided for calculating damage on an areal basis. Preliminary lists of residential and agricultural subclasses are as follows:

Residential	Agricultural
Mobile homes	Water bodies
Single family low density	Undeveloped pasture
Single family medium density	Developed pasture
Single family high density	Row crops
Multi-family low density	Truck gardens
Multi-family medium density	Cultivated forest
Multi-family high density	Natural forest

Subclasses for the other property classes will be developed in the proposed study.

72. Space for the following data items will be allotted in the master data file for each damageable property of the Residential and Agricultural classes. Similar data sets will be developed for each of the other property classes in the proposed study.

	Residential
class	depth/damage curve
subclass	ground elevation
location	first floor elevation above ground
waterway	density
basin	vacancy factor
subbasin	structure value
reach	contents value
update date	value date

	Agricultural
class	depth/damage curve
subclass	ground elevation
location	crop type
waterway	season
basin	vacancy factor
subbasin	crop value
reach	value date
update date	

73. All of the data items have the same meanings as those listed in paragraph 64 except for the following changes or additions:

a. Location (Residential and Agricultural). A series of grids, with UTM coordinate referencing, that denote the location of the patch to which the data apply.

b. Basin (Residential and Agricultural). A series of grids, with UTM coordinate referencing, that denote the locations of the basins in the geographic region.

c. Subbasin (Residential and Agricultural). A series of grids, with UTM coordinate referencing, that denote the location of the subbasins in the geographic region.

d. Reach (Residential and Agricultural). A series of grids, with UTM coordinate referencing, that denote the location of the reaches in the geographic region.

e. Depth/damage curves (Agricultural). The depth/percent damage curves to be used in the damage calculation; curves are based on crop type and season. (Residential) Curve is representative of a single residential structure of the subclass.

f. Ground elevation (Residential and Agricultural). The UTM locations and elevations of any data (spot locations, contour lines, etc.) in the region.

g. First floor elevation above ground (Residential). The typical elevation difference between ground and the first floor elevation of the residential subclass.

h. Density (Residential). Number of structures per acre.

i. Crop type (Agricultural). Crop species.

j. Season (Agricultural). Day/month/year for which damage calculations are to be performed.

k. Vacancy factor (Agricultural). The percent of the region defined in "location" that does not belong to the agricultural class or subclass or contains a different crop type. (Residential) The percent of the region defined in "location" that does not belong to the residential class or subclass, or for which the density factor, first floor elevation above ground, etc., are different.

l. Crop value (Agricultural). The net value of the cropland per acre productivity on the value date.

m. Structure value (Residential). The average structure value on the value date.

n. Contents value (Residential). The average contents value on the value date.

74. The system will be designed to provide the flexibility to assign more than one land use to the same region. For example, a region may be delineated as vegetable crops (truck gardens) with a vacancy factor of 15 percent and a portion of that region delineated as a single family residential with a vacancy factor of 50 percent when the houses are imbedded in the gardens. The system will also have the capability to handle multiple cropping conditions. That is, the system will be able to account for damages when different summer and winter crops are produced on the same land.

Damage function data

75. The damage function master data file will contain the smallest volume of information of all data files, and, therefore, the design will be quite simple in terms of contents and format. The file will be developed to be the repository for all relations between water depth and percent (of property value) damage. The file will also contain functions for wave height in addition to water depth for use in coastal studies.

76. The data items for each damage function will include the following:

a. Property class.

b. Property subclass.

c. Waterway.

d. Basin.

e. Subbasin.

f. Update date.

g. Water depth and percent damage.

77. All data items except the last were described in paragraphs 61 and 64. The water depth and percent damage data entry will consist of a string of values denoting the percent damage, at one-foot* increments, to the property to which the damage function applies.

78. It will be possible to construct several different damage function data bases for the same damage survey, as described in the discussion of sensitivity analysis (paragraphs 36-39). For example, files will be constructed in this proposed study containing both the old and new FIA functions, a set of general functions derived from a review of data available at districts and elsewhere, and functions used specifically in this study in validating the developed procedures.

Flood location and elevation data

79. The water surface (flood) location and elevation must be known in the region for which damages are to be calculated. The

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* A table of factors for converting U. S. customary units of measurements to metric can be found on page 3.

minimum available data for a stream are the water surface profiles for a given storm repeat period for alternate flood control plans. The minimum available data for coastal flooding are the average water and wave height.

80. Waterway flood. The water surface profile data normally consist of a series of elevation values for the floodsheet approximately along the channel thalweg. The locations at which elevation values are available normally correspond to the locations where stream and overbank cross-section data were available for use in the backwater computations. The following data items will be stored for each water surface profile of each available storm repeat period, for each alternate plan, and for each tributary and main channel.

a. Stream.

b. Basin.

c. Subbasin.

d. Cross section.

e. Cross section location.

f. Water elevation at cross section location.

g. River mile at cross section location.

h. Up-and-down stream cross sections.

i. Reference point location.

j. Water elevation at reference points.

k. Update date.

81. A description of each data item follows.

a. Stream. Identification of the stream.

b. Basin. Identification of the basin where the stream is located.

c. Subbasin. Identification of the subbasin where the stream is located.

d. Cross section. Identification of each cross section for which data are included in the file.

e. Cross section location. The UTM coordinates of the left- and right-bank ends of each cross section.

f. Water elevation at cross section location. The water surface profile elevation at each cross section location.

g. River mile at cross section location. The river mile location of each cross section.

h. Up-and-down stream cross sections. Identification of the closest up-and-down stream cross section to each cross section.

i. Reference point location. The UTM coordinates of all reference points.

j. Water elevation at reference points. The water surface elevation at all reference point locations calculated from the water surface profile.

k. Update date. Date when the water surface profiles were calculated.

82. The water elevation data will be stored with a resolution of at least one half foot (0.1 m) since the difference between the 100-year and standard project flood elevation is frequently less than one foot. The capability to store cross-section spatial location data to less than 32.8-ft (10-m) resolution will be incorporated into the system since multiple cross sections at bridges may be spaced at that distance from each other in the backwater computations.

83. Water surface profiles are sometimes developed in an empirical fashion, using gage and post-flood survey data. Data for water surface profiles based on these data can also be included in the master data file by selecting cross sections on the basis of the profile rate of change; cross sections can then be located on maps and the spatial location data gathered. Cross section profile data are not required unless the profiles are used in a backwater calculation for which this file would be one input. Specific procedures for generating the required data will be given in the study.

84. Coastal flood. The capability to store the same data items listed in paragraph 80 will be adapted for coastal flood calculations except for the "river mile" data entry. The term "cross section," however, will have a different meaning from that for waterway floods. Cross sections for coastal flood calculations are located as shown in Figure 7. If the water depth and wave size are constant over the entire region, only two cross sections need be defined (and a single

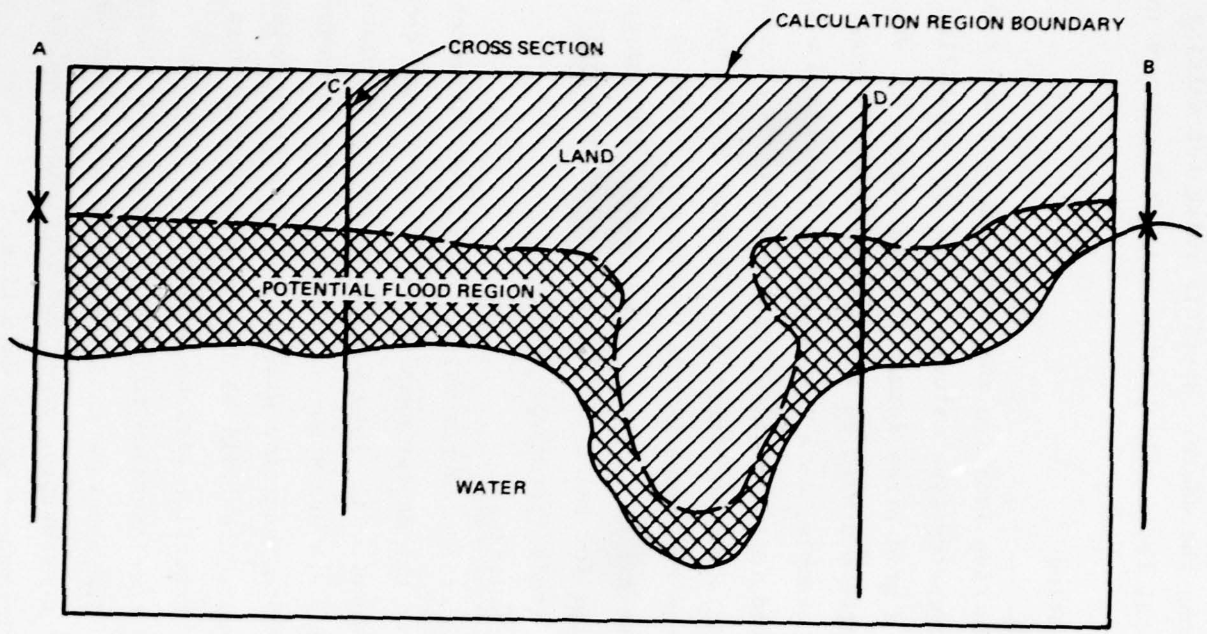


Figure 7. The location of cross sections for a coastal flood calculation

reference position chosen) as shown by cross sections A and B in Figure 7. However, the system will permit damage calculations with different wave heights and/or water elevations by choosing as many cross sections along the shore as necessary to define a water or wave surface profile along the shore. Specific rules for setting up the data base for coastal flood calculations will be developed in the proposed study.

Ground surface location
and elevation data

85. Ground surface location and elevation data are required for areal damageable property type calculations. The capability to store elevation data in a grid array format for the region for which calculations are to be performed will be included in the data base, as shown in Figure 8. For example, data over only the floodplain within the reaches are required for a waterway type calculation. The data format on magnetic tape is shown as Figure 6. The grid resolution for the individual study can be chosen by the system user based on the complexity of the land use and topographic relief within the damage aggregation reaches. Rules for selecting the grid spatial resolution will be developed in this study (paragraph 47g).

Master data files building

86. A series of procedures will be developed for entering processed data into the master data files. The proposed computer programs used to insert data into the files and their relation to the different types of data are shown in Figure 9. The procedures to be developed for data insertion will be particularly simple since the data processing procedures will be designed to produce data in a format for direct insertion with no manual intervention.

87. Each of the insertion computer programs will operate in a similar fashion. The programs will perform an edit check on the input data for internal consistency, order the input data, and merge the input data into the proper master data file.

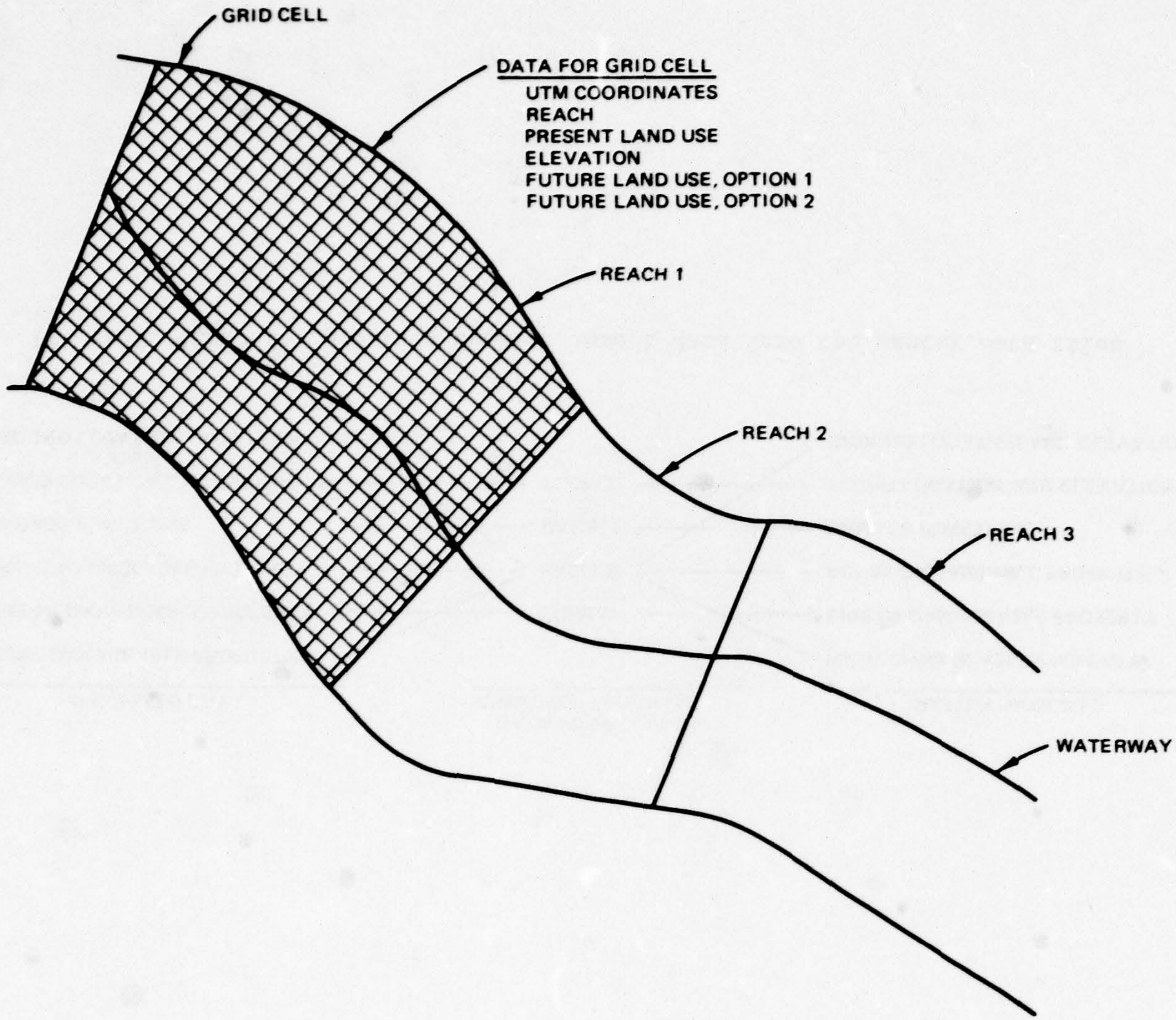


Figure 8. Grid array format of areally distributed data

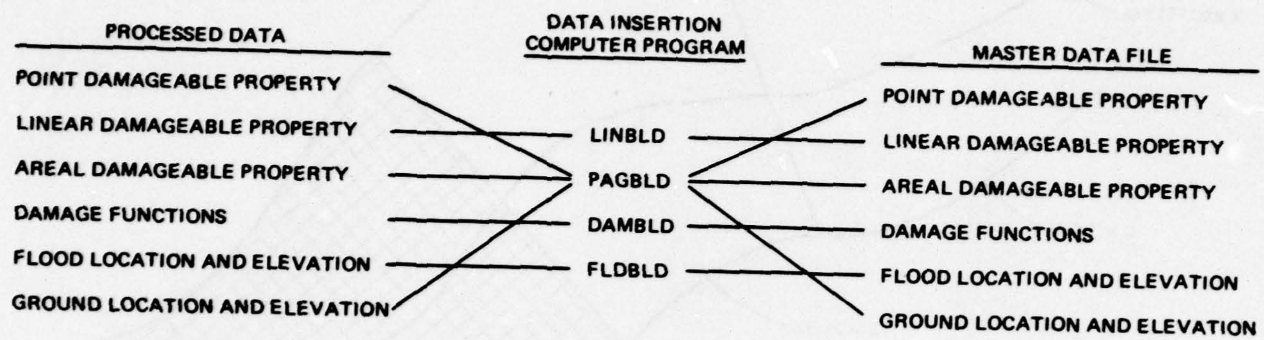


Figure 9. Computer programs used to insert data into the master data files

Master data files
editing and update

88. Straightforward procedures will be developed for editing and updating the master data files, making maximum use of other procedures developed in this proposed plan.

89. Editing. Editing involves the detection and correction of errors. The errors can include incorrect values, misassignment of data sets, incomplete data sets (some items missing in a data set), missing data sets (all items in a data set missing), and extraneous data sets or items in data sets. The range of steps involved in editing includes data set and item deletion, value replacement, and addition.

90. The detection of erroneous data will be accomplished through use of the displaying procedures described in paragraphs 95-111. In summary, it will be possible to probe the data files for any type data or data combination with a computer program and display the result in tabular and graphic form. This low-cost detection method is particularly efficient for detecting and locating errors in voluminous and complex data files with 100 percent efficiency.

91. A capability for correcting any located problems will make use of one of two procedures, shown in Figure 10, depending on the magnitude (volume and distribution) of the incorrect data.

92. The same procedures used for data processing will be used for reproducing a corrected data set if there are numerous errors scattered through the file or over the study region, or if large groups of errors are isolated in sections of the file. The processing procedures will permit the overlay of the data already on file with corrected data.

93. Procedures will be developed for each type data file for changing, adding, or deleting data. It will be possible to perform the corrections for all data entries for a given data type (e.g. insert data for a residence not previously in the file) or for selected data entries (e.g. change the ground floor elevation and structure type for a residence already in the file).

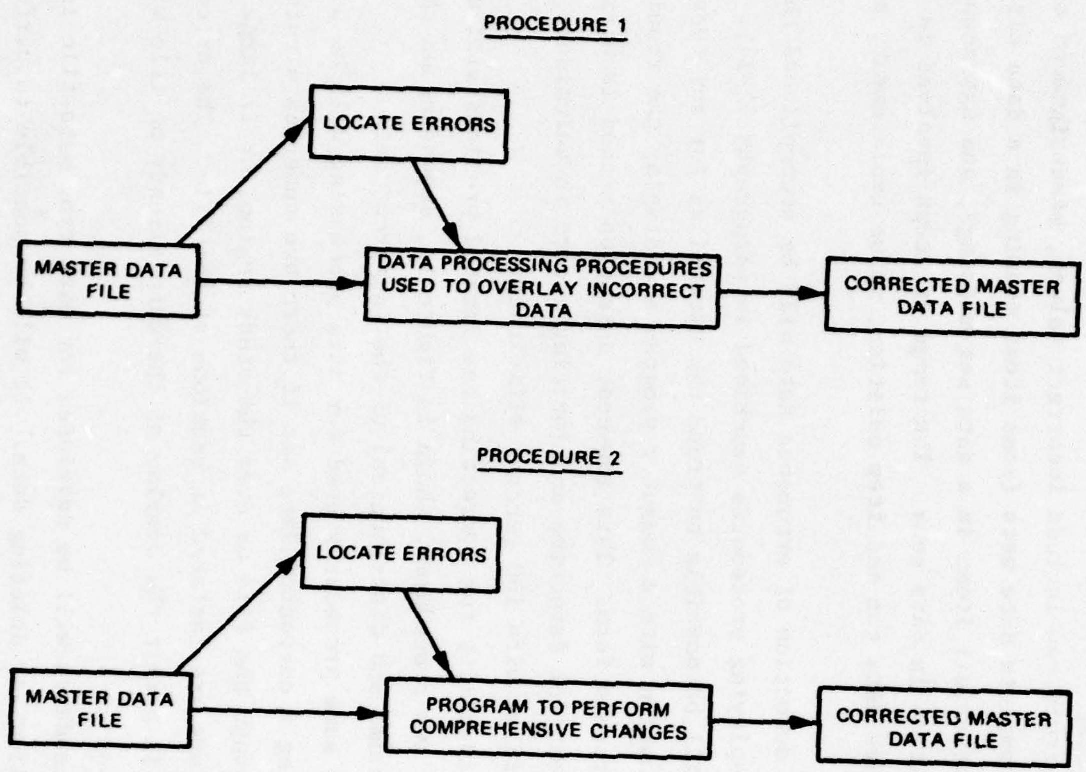


Figure 10. Two procedures for correcting a data file

94. Updating. Updating any of the master data files can be accomplished primarily through the use of the editing procedures. The updating process may, however, involve the retention of the present data (e.g. present land use) and the construction of another data item (e.g. future land use) by duplication of the present data with some changes. This option will be useful for adding updated information while retaining the available data, particularly when the updated data do not present a significant change. Programs will be developed for duplicating a complete data file and for duplicating one type data in the same data file. The duplicating procedure will consist of a single uncomplicated computer program capable of handling any data file. The duplicating operation would be performed to retain a copy of the file prior to changes or to produce several sets of duplicate files as the basis for several types of changes.

Master data files display

95. Procedures will be developed for displaying the contents of the master data files in both tabular and graphic modes. The object of the display is to provide a rapid, simple, inexpensive means of portraying the data on file. The data displays will have the capability to show selected data used in damage calculations for inclusion in reports, the total data set for a permanent paper record of available data, or to show the data in a form most convenient for validation.

96. A single computer program, MASDIS, will be developed to access any of the master data files and process any number of retrieval operations in a single program run. The program user must specify the display mode, data type, and any constraints on the data retrieval for any given single operation. The input requirement by the user will be kept to a minimum. MASDIS will internally edit the user requests for internal consistency and consistency with the master data files' contents.

97. The graphic displays will be produced with standard CALCOMP commands so that the graphic output portion of MASDIS can be used on all flatbed and drum plotters and approximately 90 percent of all special purpose plotters, such as CRT and microfilm. The tabular

displays will be produced such that the output is obtainable on any high-speed printer with at least a 132-character width line.

Tabular display

98. MASDIS will be designed to produce tabular displays of the total data sets or selected portions of the data sets from any master files. A set of tabular data column headings will be provided as an integral part of the program. These headings will be automatically printed on each data column when a report is produced. It will be possible for a user to substitute headings of his choice for the standard headings supplied in the program.

99. When total data sets are displayed, the entire contents of the data files will be reported, including those data items for which there are no data. Codes will be used to specify the absence of data in the tabular output.

100. The user can select any portion of the data for display by the use of one or more and/or-type constraints on the data search. For example, a request can be made for all residential structure data with a value date prior to five years ago. Such a search, although almost trivial, would be useful in meeting requirements of the proposed ER 1105-2-80. As a second example, a request can be made for all commercial structure data of the subclasses "wholesale" and "retail" within a specific subbasin and all residential structure data of the subclass "multi-family" within the same subbasin. These example retrieval specifications are shown below; if a data item satisfies the listed constraints, it is retrieved and tabulated.

Example 1 Constraints

point damageable property data file

data class - residential

value date - prior to 1972

Example 2 Constraints

point damageable property data file
data class - commercial
subbasin X
data subclass - wholesale

OR

point damageable property data file
data class - residential
subbasin X
data subclass - multi-family

OR

point damageable property data file
data class - commercial
subbasin X
data subclass - retail

101. Other important MASDIS options will be to sort and group the retrieved data prior to display and indicate the location of individual data items in the data files if requested by the user. These features are necessary to arrange the data for easy review.

102. It will be possible to sort the retrieved data on the basis of any data entry. For example, the output can be sequenced by value date, or structure value, or location (north to south, east to west, or distance from a specified location). It will be possible to multiple-sort the data. For example, the data can be sorted by basin, subbasin within each basin, and east to west within each subbasin.

103. The data can be grouped by any of the data entries. Tabular readings will be provided by group. For example, the data can be

grouped by basin (irrespective of the manner in which the data are sorted within a group).

104. Each data set (e.g. set of data for a given structure) will be assigned a "line number" which will be sorted in the data files with the data. The presence of line numbers will simplify the task of locating any data item in the data files for editing. It will be possible to display, as a special option, the data line numbers on any displayed data.

105. When linear and areal data are retrieved, there will be an option to calculate and report property length and area, respectively, in addition to the other options described above.

Graphic display

106. All tabular display retrieval options (paragraphs 98-105) will be operational for graphic display, except for the sorting of data, which has no meaning when data are presented in a map or graphic format. Figure 11 is a simple example of computer-plotted areal data, showing the subbasins of the Wolf River Basin. The data, contained in a master data file consisting of 200- by 200-m resolution grids, are plotted at a scale of 1:250,000. Figure 12 is a reproduction of the topographic map for the mosaic indicated in Figure 11. Figure 13 is a computer plot of the land-use class boundaries for the same mosaic. The data, contained in a master data file consisting of 25- by 25-m resolution grids, were plotted at a scale of 1:12,000.

107. Damage function data will be displayed graphically in a manner similar to the example shown in Figure 14, i.e., with river stage on the vertical axis and percent damage on the horizontal axis. There will be an option to place vertical and horizontal lines within the axes for ease in reading values from the data. In the example shown in Figure 14, the lines are placed at two-foot and five-percent intervals on the vertical and horizontal axes, respectively.

108. Any maps plotted by MASDIS can be produced at any desired scale. The user will have the option of specifying either the map scale or the UTM coordinates and physical dimensions of the map. If

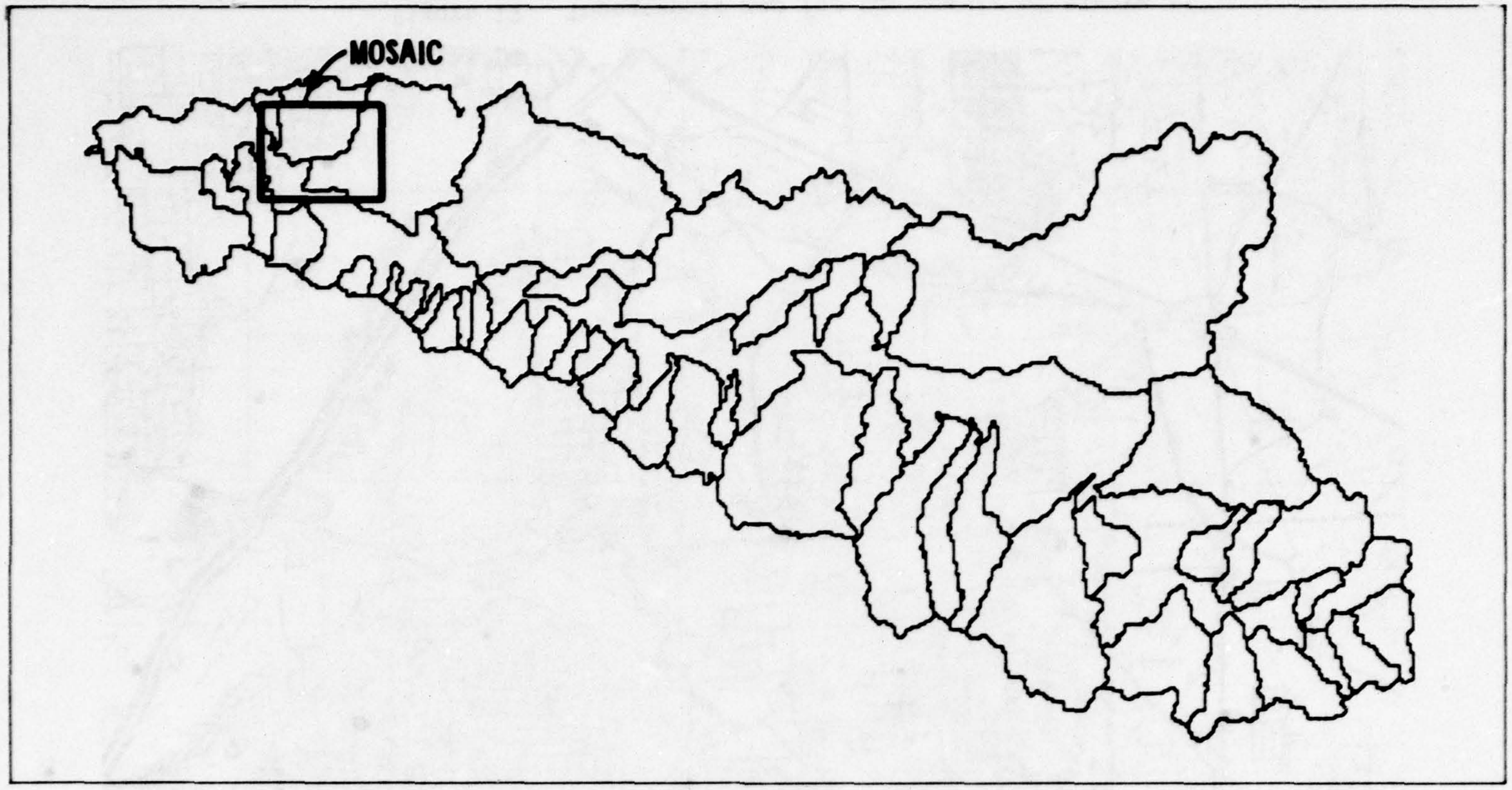


Figure 11. Computer plot of subbasins within the 825-square mile Wolf River Basin

scale: 1:250,000

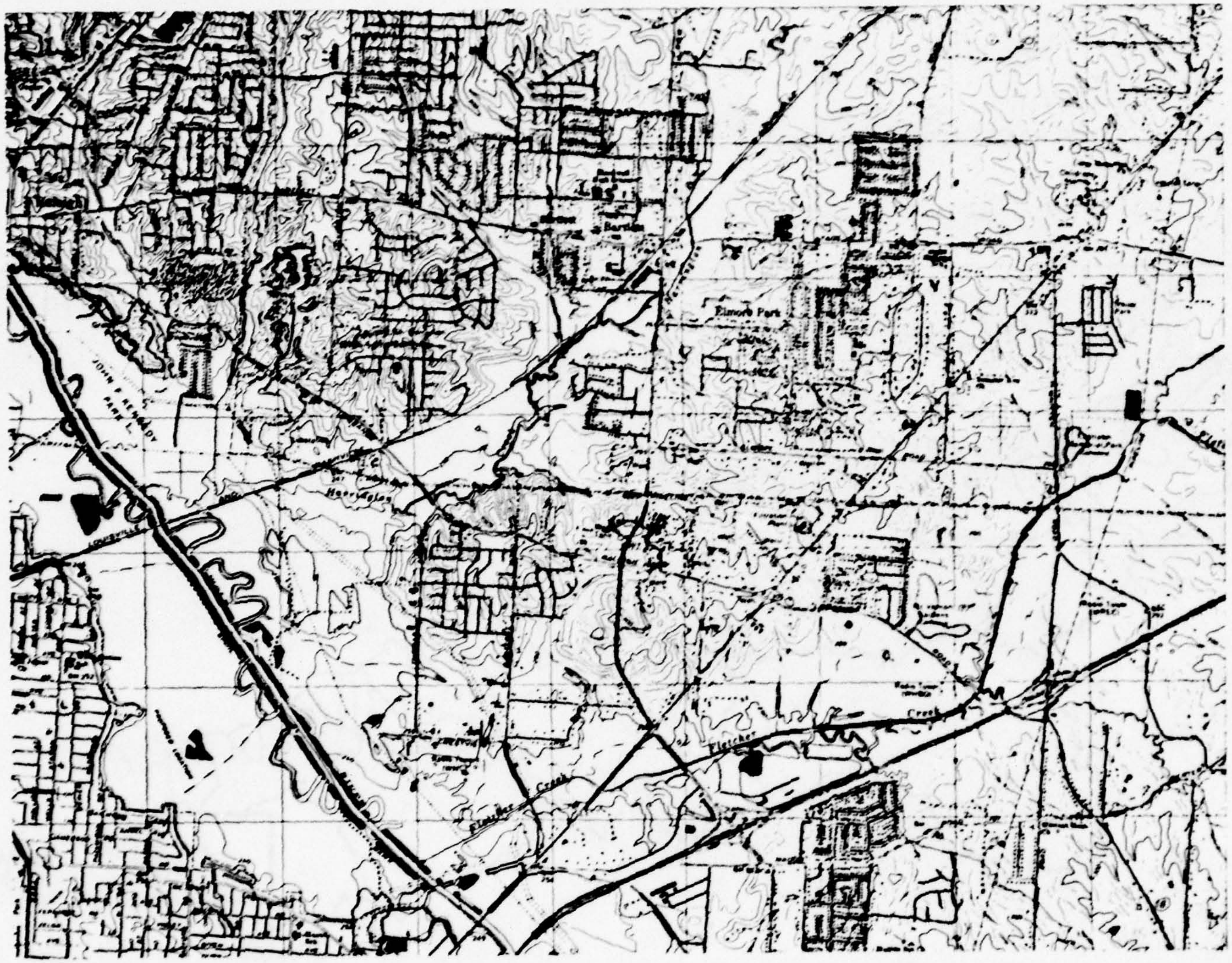


Figure 12. Topographic map for the mosaic of Figure 11

Reduced from an original
map of scale: 1:12,000

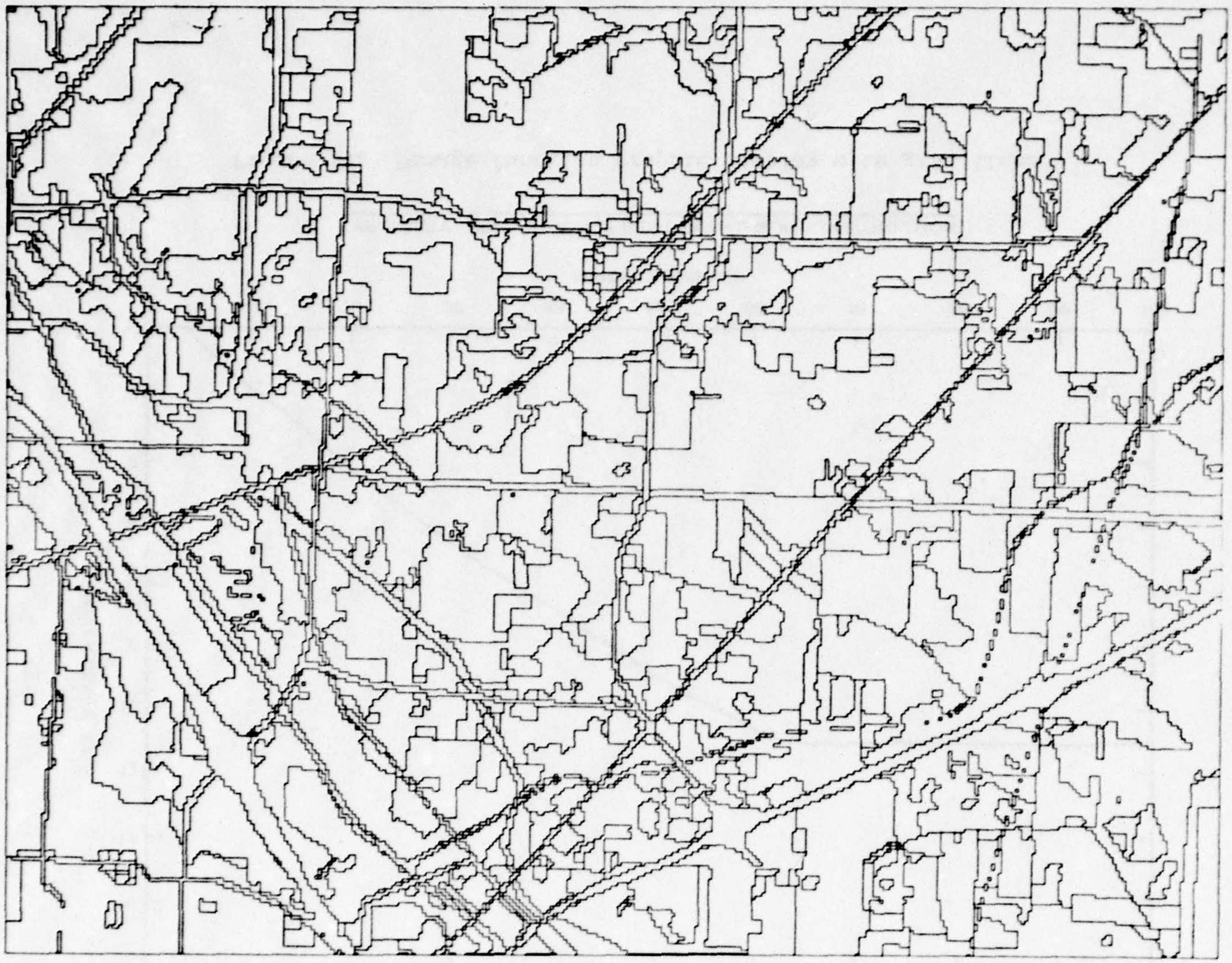
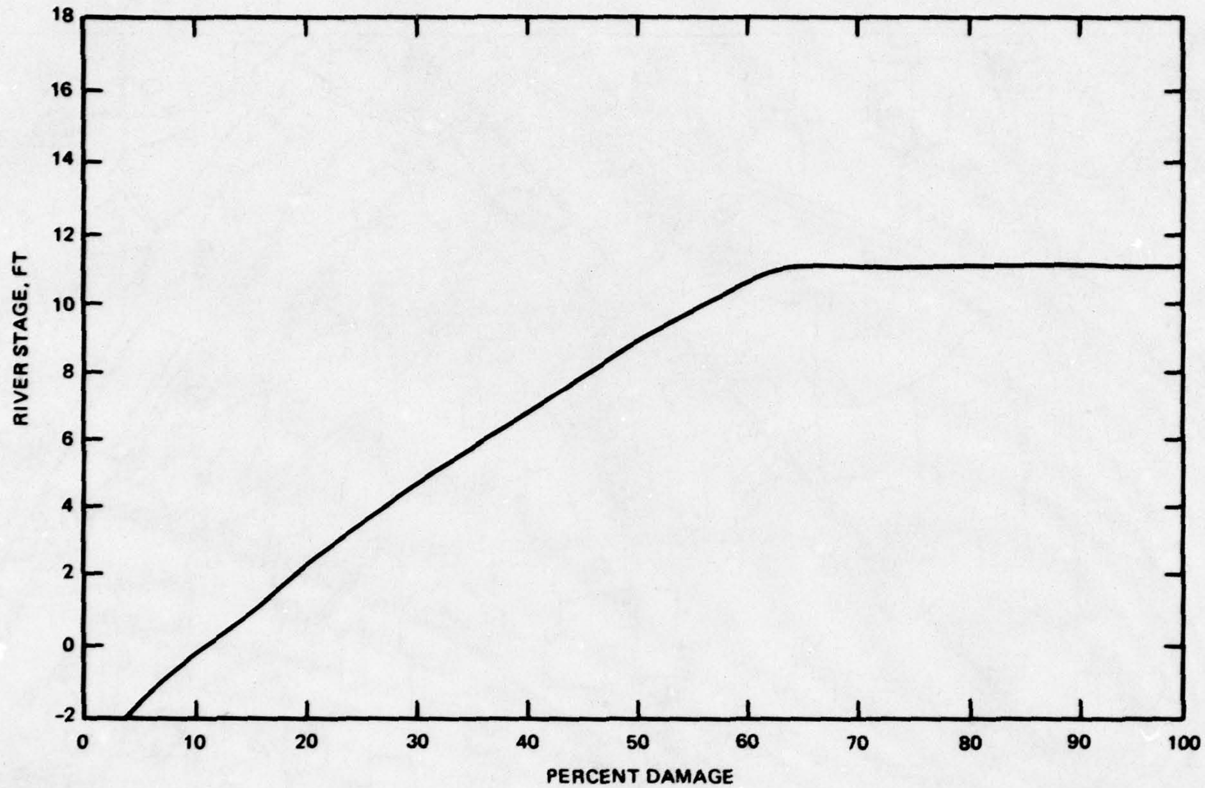


Figure 13. Computer plot of the land-use class boundaries for the mosaic (Figure 11)

Reduced from an original
map of scale: 1:12,000



PROPERTY: SINGLE FAMILY RESIDENTIAL–SLAB CONSTRUCTION

Figure 14. Damage function graphic display with grid lines

the map scale option is used, a rectangular shaped map will be produced at the required scale. The coordinates option can be used to produce rectangular-shaped maps equivalent to those produced with the map scale option or to produce scale-distorted maps. Distorted maps are frequently required to check data against aerial photographs that have not been rectified.

109. Point data will be plotted as symbols. Linear data will be plotted as lines with symbols at the locations of data points. Areal data will be plotted as lines delineating areas as shown in Figures 11 and 13. Designators will be plotted, as an option, to identify the data on the map.

110. The user will have several options for presentation of the designators. The designators can consist of code numbers to be used with an accompanying legend or data values. Figures 15 and 16 contain a representation of a map with code numbers and the accompanying legend, respectively. MASDIS will plot the data to the accuracy given by the location data. The user can choose the data types to be listed in the legend and can specify the ordering of the data columns. For example, Figure 16 shows a legend containing only three of the data items for each retrieved data entry--class, subclass, and structure value.

111. When the user specifies the use of a data value as a designator, the value of the data item specified will be used as the designator. For example, all residential data within a specified region can be retrieved, the locations of the structures plotted, and the structure value plotted next to each point location as the designator. An example is given in Figure 17. A legend will not be produced when a value designator is requested.

Damage Calculations

112. Two computer programs will be developed to provide the damage calculation capability. The first program, ESTDAM, will provide

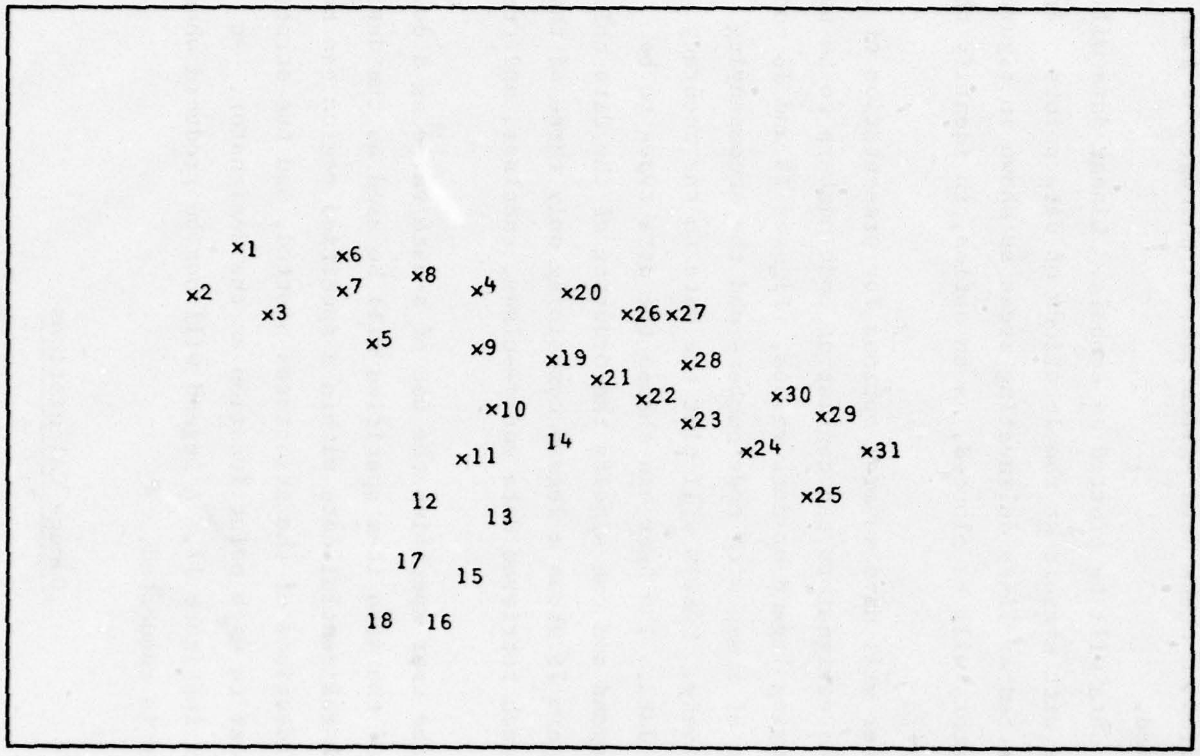


Figure 15. Representation of map with code number designators

	Data Item		
Code Number	Class	Subclass	Structure Value, $1000
1	Commercial	Retail	26
2	Commercial	Retail	85
3	Residential	Multi-family	127
4	Residential	Multi-family	320
5	Residential	Multi-family	150
--	--	--	---
--	--	--	---
30	Commercial	Retail	90
31	Commercial	Wholesale	420

Figure 16. Legend for map represented in Figure 15

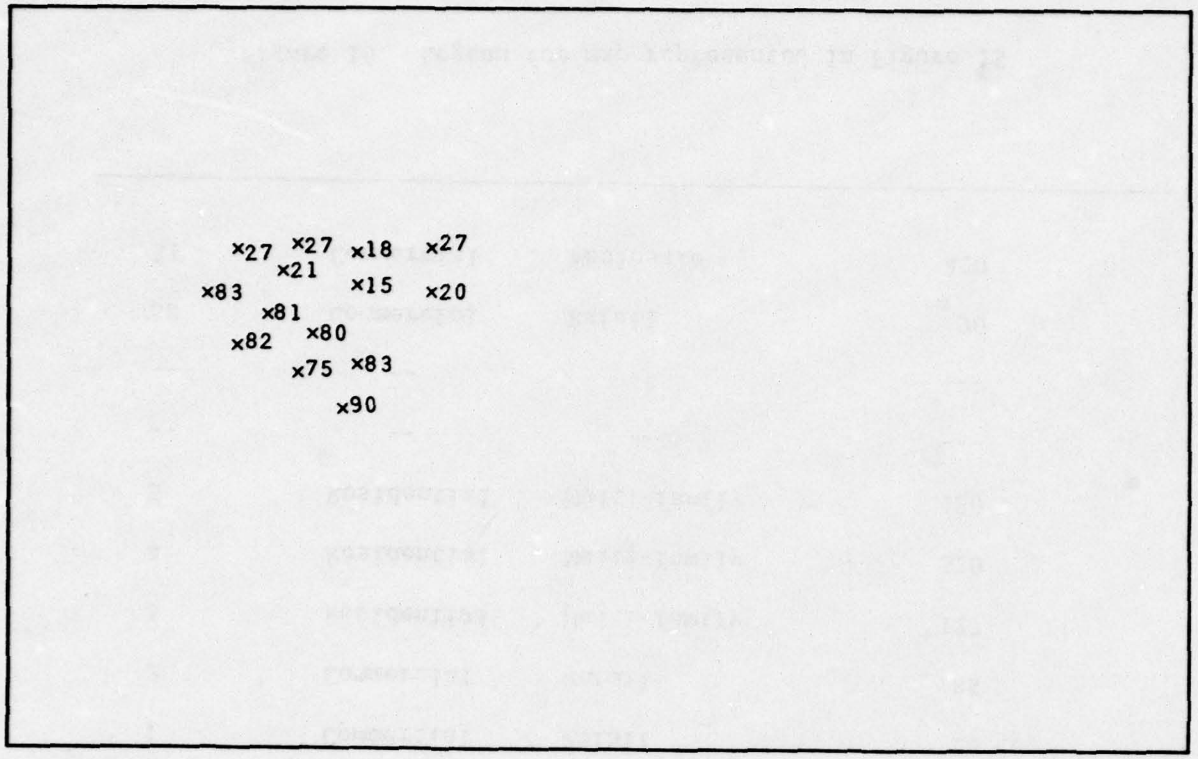


Figure 17. Representation of map with value designators, structure value in thousands of dollars

a calculation of estimated damages. The second program, AGREDAM, will provide a capability to aggregate the estimated damages calculated with ESTDAM.

Computer program ESTDAM

113. The program will permit the user to specify which calculations are to be performed and where (names of the master data files) the input data are located. ESTDAM will perform the calculations while checking the consistency of all input data and provide a complete report as to what was done and what data inconsistencies or suspicious circumstances were located. The following list shows the major conditions set by the user.

a. Type calculation to be performed.

b. Geographic region.

c. Property class and subclass.

d. Alternate plans.

e. Storm repeat periods.

ESTDAM will perform calculations for each storm repeat period, for each of the alternate plans, for the type property, and for all geographic regions specified, using the type calculation requested. It will be possible, therefore, to perform a series of calculations in one operation. For example, the 2-, 5-, 10-, 25-, 50-, and 100-year storm floods can be calculated for all alternate plans for a given region. As another example, it will be possible to calculate damages for one set of storms within one geographic region and a second set of storms within a second region.

114. The user may also set other calculation conditions, and multiple calculations can be performed with different values for those conditions. For example, a series of calculations can be performed, all in one computer run, to examine the effects of changes in residential contents damages based on different assumptions of affluence factors and different affluence growth periods.

115. Three methods of calculation will be optional in ESTDAM: reference point, zonal, and ground surface and flood sheet (hereafter termed "sheet").

116. Using the reference point method, a series of reference points must be selected by the user in the data gathering phase and entered into a data file in the data processing phase. At least one reference point is normally selected for each reach as shown in Figure 18. No further effort need be expended in preparing point source (e.g. residences) data for calculations. Additional work must be performed on linear feature (e.g. roadways) and areal feature (e.g. crops) data before performing a reference point type calculation. The features must be subdivided into sections of relatively uniform elevation and assigned average elevations so the ESTDAM program can relate the data, reference point, and water surface profile elevations for the calculations. Most Corps districts presently use a reference point method, primarily because it is a convenient manual procedure, although some confusion is caused by the amount of bookkeeping involved and the constraints this procedure places on sensitivity analysis.

117. Zonal calculations are performed by a few Corps districts. This type calculation is primarily a method of data aggregation based on the reference point type calculation. The calculational procedure is amenable to approximations so that manual labor can be decreased. The manner in which the approximation is performed yields most accurate calculations for the period of record flood for the zone and less accurate approximations for other floods with shorter return periods. Figure 19 illustrates three zones of a reach.

118. In a sheet calculation, the program will use the structures, the ground surface elevations (for land-use and agricultural type calculations) and locations, and the elevations of the flood sheet as the basis for calculating the depth of flooding. ESTDAM will calculate the three-dimensional flood sheet location on the ground surface between cross section locations used in the backwater calculations of the water surface profiles. The water surface profiles calculated using backwater computer simulations or empirical data will be the basis of all water surface elevation data used in the damage calculations. When water surface profiles are required for storm repeat

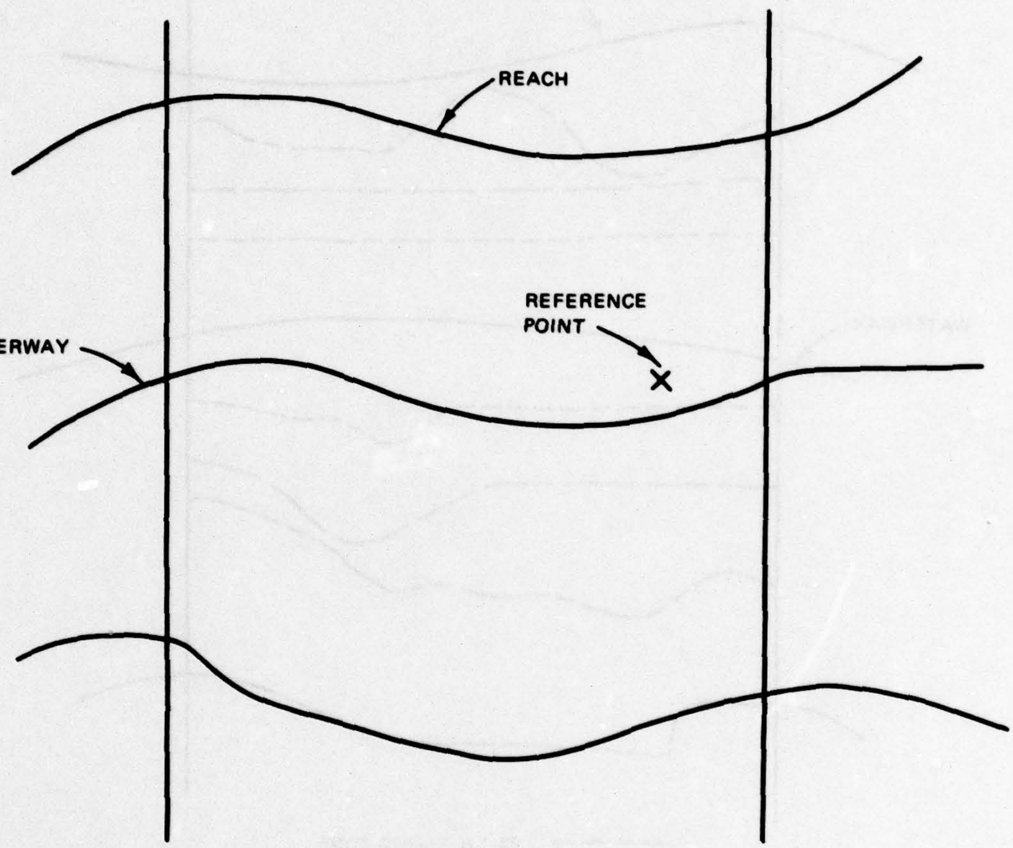


Figure 18. Reach with a reference point for an ESTDAM reference point type damage calculation

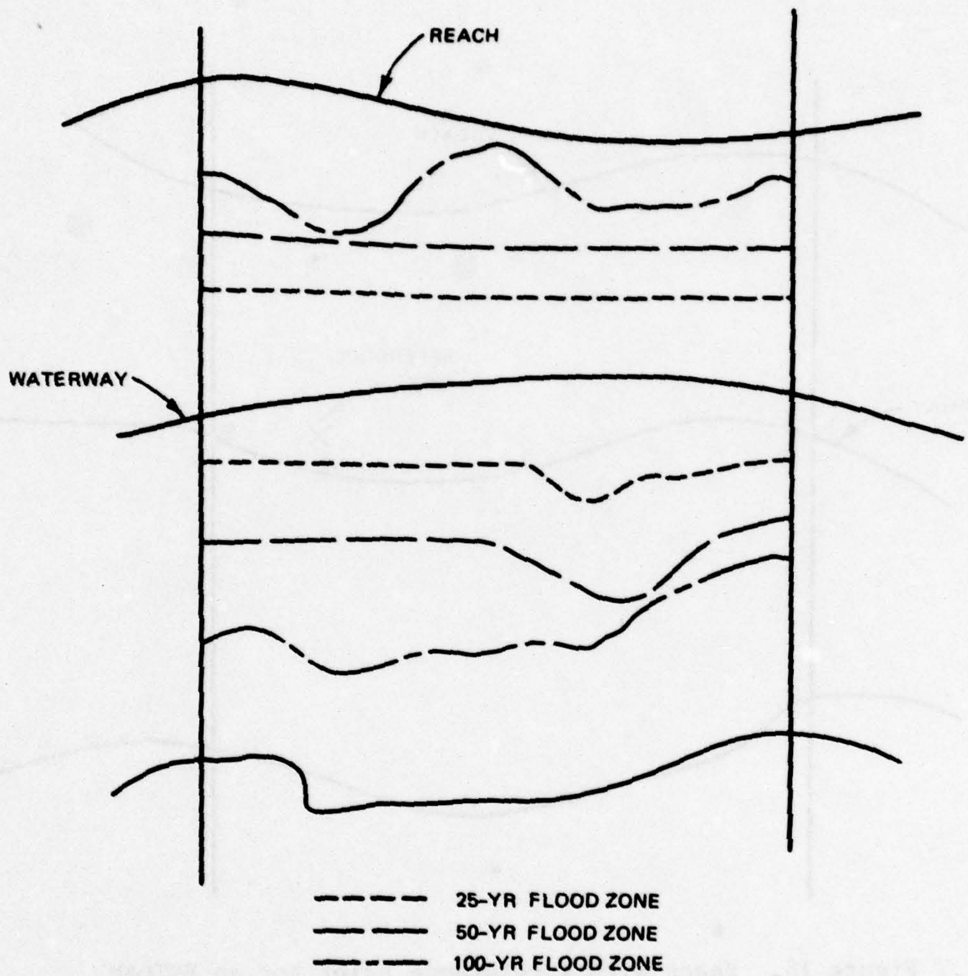


Figure 19. Zones for zonal type calculation

periods other than those for which calculations are provided, the needed data will be automatically interpolated from the backwater curves for the bounding flood repeat periods. It will not be necessary to assume that the flow lines are parallel.

119. ESTDAM will have the capability to calculate single and multiple repeat period floods and will output the data for estimated annual damage with or without discount and affluence factor effects for aggregation by AGREDAM. The types of damageable property include those in the point, linear, and areal data files.

120. The chosen geographic region of the calculation can be the entire region spanned by the data on file or any geographic subset. For example, calculations could be run for a specific subbasin(s), reach(s), repeat period zone(s), or waterway(s).

121. Alternate plans include not only different flood control plans for the same land-use conditions, but also different land-use conditions for the same flood control plan and different land-use conditions for different control plans. For example, it will be possible to perform a series of calculations to examine flood effects of no dredging, dredging, and dredging with floodplain enchroachment, using the present-day land-use distribution as the economic base.

Computer program AGREDAM

122. AGREDAM will be developed for aggregating and reporting, by tabulation and graph, the results of ESTDAM calculations. The user will be able to choose the type of aggregation. Since ESTDAM will produce a file that AGREDAM will use as input data, it will be possible to perform several types of aggregation in one run or successive computer runs without change or damage to the original input data obtained from ESTDAM.

123. AGREDAM will perform, at the option of the user, four general types of operations on the ESTDAM data and report the results in tabular form. The operations are: ordering, selective retrieval, simple aggregation, and estimated annual damage analysis. Each of these operation options to be offered to the user is described in the following paragraphs.

124. Ordering. The ESTDAM results will be tabulated after ordering the data by criteria set by the user. For example, the data could be ordered by damageable structure type, the data for each structure type ordered by reach, and the data for each reach ordered by structure subtype (multi-family housing, high density single dwellings, etc.). A special option will be to list the data as they were calculated and placed in the output file by ESTDAM. It will be possible to examine the damage calculation on a structure-by-structure or grid-by-grid basis for close quality control of the damage calculation.

125. Selective retrieval. The user can request retrieval of a selected subset of data from the ESTDAM output. For example, the calculation results could include several subbasins, but the user could request the retrieval and reporting of only data for one reach of each subbasin. The ordering feature can be used in conjunction with the selective retrieval.

126. Simple aggregation. The aggregation of damages for single-event analysis can be accomplished. The aggregation base will be at the option of the user and can be selected as reaches, subbasins, tributaries, etc. Totals and summaries will be provided for whatever data are aggregated; the number of structures, length of linear features, and acres will be provided in addition to the dollar damages. It will be possible to perform single-event calculations on subsets of the data by using the selective retrieval option and arranging the retrieved data with the ordering option in the output format desired.

127. Estimated annual damage analysis. An estimated annual damage calculation will be performed, on request, on a unit damageable property basis. That is, a calculation will be performed on a structure-by-structure, length-by-length, and area-by-area basis. The user will be able to perform the calculations for selected regions by using the selective retrieval option, aggregate the results by using the simple aggregation option, and arrange the output by using the ordering option. For example, it will be possible to produce tables of estimated annual damages for each structure, for all structures by reach, or for

all structures by type and reach. Totals and summaries will be provided for the aggregated results.

128. All tabular output will be on the computer high-speed printer. The output will contain appropriate table notation, column headings, and spacings and delimiters between data sets in both the vertical and horizontal directions. The goal will be to provide tables that are understandable to other than ADP personnel and can be used directly in reports without extensive reworking.

129. AGREDAM will produce only one type of graphic output, and it will be produced only if a sheet type calculation is performed with ESTDAM. The graphic output will be a computer plot of a plan view of the floodwater boundaries on the ground. The plot will be produced at a scale specified by the user, or as an overlay to a base map. For example, the outline of the flooded area for an FIA map can be plotted as an overlay to a USGS topographic map. The plot could be produced on the base map rather than as an overlay if a flatbed plotter is used and the base map is mounted as the plotting medium.

Sensitivity Analysis

130. A sensitivity analysis requires a series of repetitive calculations and an analysis of the results relative to each other. The number of repetitive calculations depends on the type sensitivity analysis to be performed. The type sensitivity analysis also determines the manner in which the parameter values are varied.

131. Procedures will be developed for performing a sensitivity analysis. Rules will be given for preparing the data for the analysis, performing the analysis, and interpretating the calculation results.

Data preparation

132. A few minor computer programs will be developed to aid in the construction of data files with data variations. The programs will be useful for all types of data used in the calculations and will permit the variation of individual data items (e.g. elevation of a

commercial establishment) or classes of data items (e.g. elevations or density factor of all residences). The data variation choices can be systematic or be controlled by a probability distribution. In a systematic variation, the values are all changed in the same manner, i.e., the elevations of all agricultural lands are lowered or all residential property values are increased. In a probability distribution variation, the values are changed according to a probability distribution that corresponds to an error function for the data. For example, the distribution of number of residences as a function of residence value is a probability distribution to be used for residence value. Normally, the mean is used in a calculation.

133. A list of parameters that could vary in a sensitivity analysis is given in Table 2. The previously described procedures for processing and adding or editing data in the master files will be used in a sensitivity analysis without any changes.

Analysis

134. Analysis will consist of the repetitious operation of ESTDAM and AGREDAM and the preparation of the results in a form to aid interpretation. The procedures for operation of ESTDAM and AGREDAM will be identical to those normally used. Instructions and examples will be given for the preparation of synopsis graphs and tables to aid interpretation.

Interpretation

135. A limited discussion of the interpretation of results with examples will be given in the reports to be prepared in the proposed study.

PART IV: TECHNOLOGY TRANSFER

136. This study is intended to provide flood damage calculation aids to Corps district and division personnel. A major goal of the study is to make all developed procedures immediately transferrable. All computer programs will be prepared in a basic form of Fortran IV for ease in transfer between computers. All computer programs will be prepared on the WES computer, but will be developed to operate on limited memory size computers so districts will not be forced to use a specific computer. All procedures and computer programs will be fully documented and verified. The reports to be published during the course of this study will be a primary means of technology transfer, but information exchange and training meetings will be conducted as appropriate.

Customer Confidence

137. To provide a basis for district confidence, the procedures will be tested against one or more studies being conducted in the districts. For example, the Wolf River Floodplain Information Study being prepared by WES for Memphis District has been tentatively chosen as a test study. Work on damage calculations for this study is scheduled for FY 79. Data files for land-use, structure-by-structure, and agricultural damage calculations will be available for use in this study.

138. Another attempt to promote customer confidence in the procedures involves the extensive incorporation of existing reputable procedures and computer programs into the new procedures. Many of the procedures and computer programs developed in the Wolf River study being conducted at WES, as well as the damage calculation program DAMCAL developed at HEC, will be usable in this proposed study. For example, WES's sheet flow and HEC's DAMCAL computer programs will probably be combined into a single, more general program with increased output capability to meet the districts' requirements. Further, the

IWR has sponsored the development of many technical aids that are directly applicable to the objectives of the study. These aids, however, are not receiving deserved attention. The proposed study would aid in transferring the available technology to the district level. Assistance will be solicited from HEC and IWR personnel to ensure that any procedures originating with them are technically correct after modification.

Reports

139. A series of technical reports describing the results of the study will be produced. A proposed list of report titles is given as follows:

Systematic Procedures for Flood Damage Calculations

- Report 1. Data Gathering
- Report 2. Data Processing
- Report 3. Master Data Base Preparation
- Report 4. Damage Calculations
- Report 5. Sensitivity Analysis
- Report 6. Summary and Overview

140. The schedule for publication and distribution is discussed in Part V. The reports will be published in loose-leaf form for ease of update and inclusion of notes and addenda by the districts as the procedures are adapted for their own use. Developed procedures will be made available as they are completed. The time schedule given in Part V contains notations as to when specific work items will be documented for the first time as well as a schedule for their compilation into the final reports.

PART V: TIME SCHEDULE

141. The proposed study can be completed in three years although publication of the last report, Report 6, is scheduled for distribution within 38 months of the study initiation due to printing plant scheduling.

Table 1

Selected Data Sources and Their Possible Uses

Selected Data Source	Possible Uses
	study base maps 1,2,5
1. topographic maps	structure locations 1,2,4,6,7,8, 9,15
2. orthophoto base planning maps	structure values 8,9,10,13,15,17, 18,19,20,21
3. planning commission land-use maps	structure depth/percent damage relations 8,9,13,15,17,19,20,21
4. Architect-engineer firm developed land-use maps	structure identities 2,4,6,7,8,9, 10,15
	structure elevations 1,3,5,7,9
5. topographic contour plates	land-use identities 1,2,3,4,6,7,8, 9,10,15,16
	land-use locations 1,2,3,4,6,7,8,9, 10,15,16
6. non-stereo aerial photography	land-use values 8,9,10,15,16
7. stereo aerial photography	land-use depth/percent damage relations 8
8. windshield survey	land-use elevations 1,5,7,9
9. field measurements	agricultural identities 2,3,4,6,7, 8,9,10,11,12,15
10. county agent interviews	agricultural locations 1,2,4,6,7,8, 9,10,11,12,15
11. Agricultural Research Service crop surveys	agricultural values 10,11,12,15
12. Soil Conservation Service crop surveys	agricultural depth/percent damage relations 8,9,10
13. property valuation books	

(Continued)

Table 1 (Concluded)

	Selected Data Source	Possible Uses
14.	water surface profiles	road locations 1,2,3,4,5,6,7,9
15.	available Corps or Engineers reports	estimated flood locations 1,2,3,4,5,6,7,14
16.	soil surveys	
17.	real estate offices	
18.	tax assessor records	
19.	building contractors	
20.	industrial managers	
21.	store owners	

Table 2

Variable Parameters of a Sensitivity Analysis

Affluence factor
Discount rate
Affluence growth time period
Discount time period
Structure elevations
Land-use elevations for regions containing nonagricultural property
Agricultural land elevations
Agricultural seasonal displacement
Hydraulic water surface profile
Depth/damage function relations
Structure contents value
Damageable property value
Land use

APPENDIX A: BIBLIOGRAPHIC SEARCH RESULTS

1. This appendix contains a list of repositories and reference material sources relevant to flood damage assessments and calculations. The repository sources listed are all specialized Federal government installation technical information centers. The reference source materials are grouped according to (a) procedures used by Corps Districts or advocated by research organizations for use by Corps Districts; (b) computer programs directly related to a procedural step in the flood damage calculation process; and (c) references containing general information.

2. The general references are primarily Corps reports and examples of Corps flood damage calculation considerations and procedures.

3. More detailed information on the available computer programs is provided in Appendix B.

Selected Federal Government Repository Sources

1. Hydraulic Engineering Information Analysis Center, Army Engineer Waterways Experiment Station, P.O. Box 631, Vicksburg, Mississippi 39180
   Telephone (601) 636-3111, ext. 3368
   Contacts: Pickett, Ellis B., DIR; Neilson, Frank M.
   Controlling organization/type of source: U.S. DOD/Army, Information Analysis Center
   Language Input: English, French, German, Russian
   Coverage: All dates
   Availability and service charges: Scientific community, charges will be negotiated for services beyond routine inquiries
   Size of collection and/or special collections: Supported by Library Branch, Technical Information Center at WES, which contains approximately 200,000 items
   Special areas of interest: Hydraulic systems, hydraulic models, hydraulic fluids, hydrodynamics, hydrostatics, fluid mechanics, fluid flow, fluid dynamic properties, harbors, dams, rivers, floods, water waves, navigation, tides, shock waves, underwater
   Services and materials: Bibliography compilation, consulting, data compilation, referral, identification service, indexing, literature surveys, loans, state-of-the-art studies, technical analysis and evaluation, technical answers, books, classified materials, microform, reprints and preprints, research reports, periodicals, science, scientific and technical data, translations, unpublished materials
   Publications: None to date

2. U. S. Army Corps of Engineers, The Hydrologic Engineering Center, 609 Second Street, Davis, California 95616
   Telephone: FTS 448-3480
   Director and contacts: Eichert, B. S., DIR
   Availability and service charges: Access unlimited
   Special areas of interest: Hydraulics, erosion, water quality
   Services and materials: Primarily research reports
   Publications: Many in various aspects of hydrology

3. U. S. Army Engineer District, Baltimore, Maryland, Technical Library,
   P. O. Box 1715, Baltimore, Maryland 21203
   Telephone: (301) 962-3423; AUTOVON: 231-3890, ext 3423; FTS 922-3424
   Contacts: Kammer, F. David, Dist. Librarian; Bernstein, Anne, Library Technician
   Availability and service charges: Department of the Army, other Government agencies, authorized and qualified contractors
   Size of collection: Primarily a book collection of approximately 13,800 books with 1,000 technical reports

Special areas of interest: Floods, flood control, dams, tides, Potomac River, water pollution, environments, rivers, planning, hydrology, water supplies, costs, drainage, ground water, natural resources

Services and materials: Loans (interlibrary), referral, literature surveys, abstracting, consulting, bibliography compilation

Publications: The District issues technical reports, some of which are available through DDC and NTIS. Others are supplied upon request by the District if no restrictions have been placed on the information by the originator. Library prepares technical bibliographies

4. U. S. Army Engineer Division, Lower Mississippi Valley, Vicksburg, Mississippi, Technical Library, Vicksburg, Mississippi 39180
Telephone: (601) 636-1311, ext. 257; AUTOVON 437-1142, ext. 257
Contacts: Johnson, Betty, Librarian
Coverage: 1800 to date
Availability and service charges: Government agencies. Submit written request for service
Size of collection: Approximately 28,000 books, 480 technical reports, 200 bound journals, 85 bibliographies. Contains much historical material
Special areas of interest: Rivers, harbors, inland waterways, Lower Mississippi Valley, floods, damage control, hydraulics, hydraulic models, navigation, engineering geology, soil mechanics, dams, levees, navigation charts, geology
Services and materials: Referral, reference, loans (interlibrary)

5. U. S. Army Engineer Division, Missouri River, Omaha, Nebraska, Technical Library, P.O. Box 103, Downtown Station, Omaha, Nebraska 68101
Telephone: (404) 221-3230; AUTOVON 271-1110 (221-3230)
Contacts: Sharp, Valetta, Librarian
Availability and service charges: Department of Defense, other Government agencies, authorized contractors, educational institutions, and the general public, subject to facility and manpower limitations
Size of collection: Approximately 10,000 books, 300 journals, plus technical report collection
Special areas of interest: Engineering, construction, water resources, floods, flooding, rivers, inland waterways, law military engineering, soil mechanics, sedimentation, drainage, blast, concrete
Services and materials: Referral, loans (interlibrary), visitor reference, consultant
Publications: Technical reports, available from DDC and NTIS

6. U. S. Army Engineer Division, Southwestern, Dallas, Texas, Technical Library, 1114 Commerce Street, Dallas, Texas 75202
   Telephone: (214) 749-2651
   Contacts: Smith, Maxine C., Librarian; Quevedo, Jim, Library Technician
   Availability and service charges: Department of Defense, other Government agencies, educational institutions, subject to facility manpower limitations
   Size of collection: Approximately 6,000 books, 2,000 technical reports, 12,000 journals
   Special areas of interest: Construction, military engineering, inland waterways, water resources, contract administration, soil mechanics, drainage
   Services and materials: Consulting, literature surveys, duplicating referral, loans (interlibrary), visitor reference
   Publications: Published technical research reports available to the public through NTIS. Provides other reports from the division to agencies with need-to-know and security clearance

7. U. S. Army Engineer Institute for Water Resources, Kingman Building, Fort Belvoir, Virginia 22060
   Telephone: (202) 325-7420, AUTOVON 221-7420
   Director and contacts: Ludwig, D. C., COL, DIR; Nance, C. A., Administration Office
   Availability and service charges: Department of Defense and other Government agencies with need-to-know and clearance
   Special areas of interest: Water resources, water supplies, floods, flood control, water traffic, environments, urban areas, agriculture, terrain, water pollution, management planning and control, costs, economics, sociometrics, econometrics
   Publications: Impact studies of water resources planning, technical test reports available through DDC. Most reports are also available through NTIS

8. U. S. Army Engineer Waterways Experiment Station, Technical Information Center, P.O. Box 631, Vicksburg, Mississippi 39180
   Telephone (601) 636-3111, AUTOVON 435-1680, FTS 542-2543
   Director and contacts: Cannon, J. L., COL, Commander & Director, Spivey, M., Library Branch
   Availability and service charges: Access unlimited except for classified materials
   Special areas of interest: All technical fields related to Corps work
   Services and materials: Referral, research, technical analysis and evaluation, translation, books, periodicals, research reports, operations reports
   Publications: Several in various engineering and library science fields

9. Water Resources Scientific Information Center, Office of Water Research and Technology, Department of the Interior, Washington, D. C. 20240
Telephone: (202) 343-8435
Contacts: Jensen, Raymond A., Mgr.
Coverage: 1960 to date
Availability and service charges: Access unlimited; services available to Government agencies on reciprocal basis by agreement; nominal charges to public
Size of collection and/or special collections: Technical documents on water resources research. Collection about 95,000 growing at approximately 13,000 per year
Special areas of interest: Water, water supplies, water treatment, water pollution, water resources, water reclamation, sediments, waste water, ground water, rivers, flow, waterworks, aquatic
Services and materials: Announcement bulletins, indexes, bibliographies, literature surveys, research reports, referral, technical analysis and evaluation
Publications: Selected water resources abstracts - semimonthly, available from NTIS. Topical bibliographies and literature surveys - available from NTIS, GPO, or as announced. Water Resources Catalog - GPO. List of research reports supported by OWRT Research - Available from WRSIC.

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4. Development and Resources Corp., "A Perspective on Flood Protection of Agricultural Lands," Contract Report 76-3 (for U. S. Army Engineer Institute for Water Resources), Dec 1976, 458 Capitol Mall, Sacramento, Calif. 95814.

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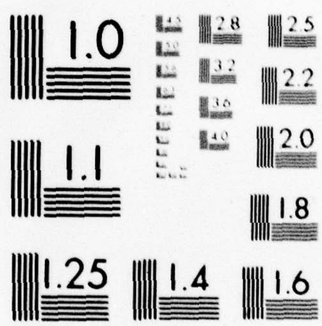

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49. __________, Solicitation, No. DS-7231 Negotiated Contract, Aug 1976 [Flood Insurance Studies, Payson, Lehi, and Salem, Utah].

50. Villines, J. R., "Economic Analysis of Flood Detention Storage by Digital Computer," University of Kentucky Water Resource Institute, Research Report 9, 1968, Lexington, Ky.

APPENDIX B: AVAILABLE COMPUTER PROGRAMS USED FOR SOME ASPECT OF THE FLOOD DAMAGE CALCULATION PROCEDURE

1. This appendix contains available summaries of computer programs. The computer program information was gathered during the literature review and does not represent the total computer program capability within the Corps district and division offices. The computer programs identified in this appendix were selected as those which could be used for some aspect of the flood damage calculation procedure.

2. Detailed descriptions and sample applications of some of the computer programs are contained in references listed in Appendix A.

PROGRAM IDENTIFICATION

Program Title: DAMAGES

Subject: DAMAGES calculates flood damages to all categories of urban and non-urban development, with and without alternative improvements, and derives benefits associated with each alternative.

Writers: Ira D. Young Date: 1970
Anita L. Nelson

Language: FORTRAN IV

Organization: Economics Section
U. S. Army Engineer District, Los Angeles

Availability: Economics Section
U. S. Army Engineer District, Los Angeles
P. O. Box 2711
Los Angeles, CA
Phone 213-688-5458

Previous Applications: DAMAGES has been in operation since 1970 and has been used to compute all flood control damages since that date. Projects evaluated using DAMAGES include Indian Bend Wash, Cucamonga, Santa Ana River, Taquitz, Gila Below Painted Rock, Warm Creek, Day, East Etiwanda, San Sevaine, etc.

Abstract: DAMAGES requires the following input data:

(1) The number of acres inundated by each size storm.

(2) The value of the development in each of those flow areas.

(3) Present and projected land use in each overflow area.

(4) Associated present values and future values per acre.

(5) Depth-damage relations.

(6) Discharge-frequency curves.

Using this information, DAMAGES calculates by land use for each year of project life:

(1) The value of damageable property.

(2) Damage-discharge relations.

(3) Damage-frequency relations and probable annual damages.

Equivalent annual damages are also calculated. Benefits are similarly displayed for providing protection against each major size flood, e.g., what would be the benefits of providing 50-year, 100-year, or standard project flood protection? DAMAGES allows for urban recycling to occur over time. Other options offered in DAMAGES include:

(1) Changing overflow areas with increased urbanization, or,

(2) Changing discharge-frequency relations with urban development in the drainage area.

Evaluation:

(1) Strengths: Quickly and accurately performs the clerical operations necessary to calculating benefits. Has much flexibility not only in options available, but also in degree of accuracy. For example, for a detailed study, data on depth of flooding and values can be quite specific, but for quick reconnaissance studies, average values will suffice. Gives planner complete picture of flooding problem over time.

(2) Weaknesses: In order to offer options, much input is required which can appear intricate until familiarity is established.

(3) Usefulness: Quite useful to planner in evaluating flood damages. His time can be spent gathering and testing data rather than grinding through repetitive calculations.

(4) Limitations of Use: DAMAGES can only provide information on flood damages with and without alternative projects.

Areas of Application in Urban Studies: Useful in assessing flood hazard and effectiveness of flood control measures in urban areas.

TECHNICAL DESCRIPTION

Methodology: A stream of values of damageable property is calculated annually for each depth, flood, and use. It averages the minimum and maximum depths, searches the relevant depth-damage curve for the damage factor associated with that average depth, and multiplies. It accumulates the resulting damages by flood. (It is generally preferable to input four major damaging floods to give shape to the damage-discharge curve.) For each of the eleven points used to describe the frequency-discharge curve, the program searches and interpolates to find the associated dollar damage. Using the end points of the frequency curve to define the limits, the program calculates the area under the damage-frequency curve. This area, called probable annual damages, is calculated annually for each land-use category. Then, it is discounted; the present worths are summed and multiplied by a capital recovery factor, producing equivalent annual damages.

One of the input elements requested is the number of acres inundated by depth intervals. If detailed information is available, the system user can enter that 40 acres will be flooded by 2 to 3 feet of water, 50 acres will be covered by 1 to 2 feet, and 60 will be under 0 to 10 feet of water (the depth intervals need not be of uniform increment; 0-1/4, 1/4-1, 1-2, are all allowable intervals). If, however, the study is at the first investigation study stage, it is also possible to use average depth figures. (It is possible to separate an establishment into its component parts and calculate damages prevented for each part. This is particularly useful in the case where distinct depth-damage relationships exist for each component, as in the case with industrial development where the structures, contents, and equipment each experience different damages at each depth of water.)

Additionally, it is possible to calculate, with and without (or total and non-preventable) project damages, the possible annual damages (being the area between the two damage-frequency curves).

DAMAGES prints benefits by land use, etc. Each of the intermediate steps, such as value of damageable property, the damages associated with each major discharge, and the related damages, are also available for output.

OPERATING DESCRIPTION

Characteristics: 2 central processing units, under 30-second run time on CDC 7600.

Hardware Requirements:
Computer Systems Used: (Control Data Corporation) CDC 7600 with extended memory or 6600. DAMAGES is operational on Lawrence Berkeley Lab computer system (CDC 7600).

Memory Requirements: 70,000 words (60 bit words)

Software Requirements: References and User Manuals:
Documentation on DAMAGES is not published. Information is supplied by Los Angeles District on an individual basis.

PROGRAM IDENTIFICATION

Program Title: A Computer Simulation Model for Flood Plain Development

Code Name: SIMULATOR

Writers: N. V. Arvanitidis et al. Date: December 1972

Language: FORTRAN IV

Organization: INTASA
Menlo Park, CA

Availability: INTASA
1120 Crane St.
Menlo Park, CA 94025

Previous Applications: Model has been applied to Reach 13 in the Connecticut River Basin and Papillion Creek in Omaha, Nebraska. It has also been implemented in the Sand and Toll Gate Creeks flood plains study for the Metro-Denver area.

Abstract: The model evaluates natural economic efficiency benefits for various levels of flood protection and alternative land-use plans. The model has three major components:

1. Calculation of flood damages and economic rent components including:

    a. Fixed area development cost
    b. Site development cost
    c. Transportation cost
    d. Amenity value
    e. Social effect

2. Allocation of land-use requirements over time based on:

    a. Land-use plans at some future point in time within or beyond the social planning horizon.
    b. A sequence of development provided as input for parts of the study area that have fixed development costs.
    c. Present values of net economic rents.

3. Location advantage based on different economic rents of flood damage and/or different land values and flood damages.

Evaluation: In the Metro-Denver Study, the program proved useful for alternative land allocation, flood damage assessment, and benefit evaluation of development in the floodplain.

PROGRAM IDENTIFICATION

Program Title: Floodplain Management System Model

Code Name: FMS, CORPSLP

Subject: The program deals with the problem of planning land-use and engineering alternatives for floodplain management

Keywords: Floodplain management, flood control planning, benefit/cost analysis, land-use planning, linear programming, economic rents, theory and application, water resources development, water resources planning

Writer: Reuben N. Weisz Date: 1973

Language: FORTRAN

Organization: Department of Agricultural Economics
College of Agriculture
University of Arizona
Tucson, Arizona 85721

Availability: U. S. Army Engineer Institute for Water Resources
Kingman Building
Fort Belvoir, VA

Previous Application: Development of a general land-use plan for Pima County, Arizona, while considering the floodplain in detail. This test application of the methodology specifically examines economic rationale and decision rules for determining the most economically efficient combination of: spatial and temporal distribution of urban land uses, site elevation through earth fill, floodproofing, public acquisition of undeveloped land for open space uses, public acquisition and removal of existing improvements from the floodplain, dams, and channel improvements.

Abstract: The program consists of a canned linear programming (LP) package combined with a driver program that sets up the LP matrix.

Evaluation: Some of the characteristic features of this floodplain management system model include the following:

(1) For each development policy and engineering alternative considered, the land-use regulation part of the model is structured as a linear activity analysis problem. A linear model is readily understood and is compatible with existing computer solution techniques capable of determining the optimal solution to very large problems.

(2) The planning model is directed toward achieving floodplain management objectives. Given an appropriate set of constraints and exogenous decisions, the model can be used to produce the most economically efficient combination of land-use regulations, development policies, and engineering alternatives.

(3) The solutions to the model can be used as a guide for subsequent action at all levels of government. On the Federal level, the model will indicate the incremental economic productivity that can be gained by including Federally funded development policy and engineering alternatives in the floodplain management plan.

On the local and state levels, the model can be used to recommend a socially desirable set of regulatory tools--zoning ordinances, subdivision regulations, and building and housing codes. The hallmark of the model is that it can consider all land-use and engineering alternatives, those modifying flood characteristics as well as those modifying susceptibility to flood damage.

(4) The model can also provide guidance on other means of attaining floodplain management objectives--i.e., means which modify the consequences of flooding if not the hydrologic and land-use possibilities. For example, one subroutine of the floodplain management system model computes the expected present value of private and public flood losses. This information can be used as a basis for establishing flood insurance premiums and tax adjustments.

(5) The sensitivity of the solution of the model to the initial input data and model formulation assumptions may be readily examined during post-optimality analysis. The results of such an examination can indicate additional input requirements and highlight data inadequacies. This information may be used to indicate how much reliance can be placed on any particular solution of the model.

(6) The floodplain management system model can account for the fact that a number of objectives may be relevant in a given planning area. Although the economic efficiency objective may be important, especially where the potential for Federal interest and investment is high, the economic opportunity cost of no longer considering this objective as a dominant criterion can be determined by comparing the value of the aggregate economic (rent) productivity associated with each solution as the

noneconomic considerations reflected in the constraint set are altered. A trade-off analysis between the economic objective and noneconomic considerations can be performed in this manner.

(7) The model recognizes that the kinds of actions taken that are peculiar to the floodplain may not be the actions that have the greatest leverage in achieving objectives. For example, in this study, site elevation, floodproofing, and engineering works do not appear to contribute as much to overall economic productivity as the actions that apply to the whole planning area--i.e., zoning ordinances.

(8) The model may provide a means for coordinating flood damage reduction proposals with other plans to satisfy the needs of the area. In the test study, the floodplain land-use regulations were coordinated with a general land-use plan for all of Pima County.

(9) The model may be used to indicate an acceptable level of residual flood losses. All losses will never be eliminated. An economically efficient floodplain management plan may necessitate a "desirable" level of residual flood losses. In general terms, this level is defined to exist at the point where the marginal flood damage reduction benefits are equal to the marginal costs of obtaining the incremental benefits.

(10) In the absence of comprehensive planning, the owner of a parcel of land may employ that land in what appears to be the best use when measured in the private account; however, this may be a suboptimal land use when viewed from the perspective of the community at large. In addition, by explicitly including offsite damages as well as site damages within the model, a social accounting stance is taken.

(11) The model provides a common measure of productivity for a variety of land-use regulations, developmental policies, and engineering alternatives; it also provides a means for bringing together a variety of information--economic, hydrologic, engineering, and urban planning. This combined with a systematic approach to formulating and analyzing a floodplain management problem will aid planners in achieving a unified approach to floodplain management.

(12) The effect of watershed development on future flood characteristics should be incorporated into the model. In this study, the implications of an assumed nonfloodplain urbanization effect on runoff, the "backwater" effect on planning decisions, and the economic consequences of planning decisions are examined during postoptimality analysis.

(13) The model distinguishes between the problem of minimizing flood damages to existing development (the residual flood damages to existing development term in the aggregate economic rent equation) and achieving optimum future development of floodplains (the aggregate site rent term in the aggregate economic rent equation). Actually, both of these concerns are subordinate to the overall objective of increasing the aggregate economic productivity.

(14) For each relevant land use, the model considers economic productivity differentials due to locational differentials and temporal differentials. The LP model simultaneously considers all land uses in all locations in all time periods when developing an optimal allocation; this differs from other approaches which develop suboptional solutions by allocating land uses one time period and/or one planning area at a time.

(15) The mixed bag of tools in the model provides the planner with a certain amount of flexibility. For example, in the test application of the model in Pima County, Arizona, staged investment in engineering works as well as staged investment in development of the floodplain were considered. As the time for investment approaches, the model can be updated to take into account changed state conditions and additional data that have accumulated since the existing plan was developed. Once this is done, the model may be rerun; the results of this analysis may suggest a modification of earlier plans for future land-use regulations and engineering works.

(16) Since the purpose of the study leading to development of the model was to develop a methodology for floodplain management, and not to develop a specific solution to Pima County's floodplain management problem, the reader should be cautioned against using the results of this analysis to make direct policy implications about specific land-use and engineering alternatives for floodplain management in the test area. However, the results of this analysis can be used to

indicate to planners the information that is required from them in this approach and the types of information which the model in turn can give to planners. For example, future interaction with local planners could result in modifying the model to include and consider:

(a) A larger number of relevant land uses, i.e. zoning classifications.

(b) A more detailed breakdown of locational alternatives.

(c) A more complete set of constraint equations.

(d) Additional development policy alternatives, such as location of public services, utilities, and facilities in places that will guide private development away from flood-prone areas.

This kind of information combined with additional input data could be used to develop solutions to the floodplain management system model which could form the basis for policy formation.

Because of the novelty of the approach outlined herein, initial implementation of the methodology may necessitate a greater effort at coordinated planning between local, state, and Federal levels of government than will be necessary in future applications.

TECHNICAL DESCRIPTION

Methodology: The methodology can consider land-use regulations such as zoning ordinances, subdivision regulations, and building and housing codes; developmental policies such as direction of services and utilities, acquisition or open space uses, redevelopment and renewal, and permanent evacuation; and engineering measures such as dams, reservoirs, levees, floodwalls, and channel alterations. The objective of the floodplain management system model is to select the most economically efficient combination of land-use and engineering alternatives. A computer-based mathematical optimization approach is used to select the combination of management alternatives that will maximize the aggregate economic productivity of all land resources within a study area subject to an appropriate set of planning constraints.

Input Data Required: No data over and above what is currently used by local and Federal planners are required.

Output Provided: The demonstration study has illustrated how the methodology can be used to: formulate floodplain management system plans and evaluate the economic impact of floodplain management system, plus, perform "with and without" analysis, perform analysis of development policy and engineering alternatives, and perform sensitivity analysis.

Hopefully, the model developed in this study can aid planners in achieving a unified, unbiased approach to floodplain management.

OPERATING DESCRIPTION

Characteristics: Typical cost of a run was in the range of $10 to $16 per run. Actual running time in future will depend on size of problem.

Hardware Requirements:

Computer Systems Used: Although the program was tested on the CDC 6400 computer this is not a limitation since canned linear programming packages are commonly available for most hardware systems.

Peripherals Required: Either card or tape input; printer output.

Software Requirements: Canned linear programming package. Drive program.

References and User Manuals:

A Methodology for Planning Land Use and Engineering Alternatives for Floodplain Management:

Phase I Report: The Value of Land in Alternative Urban Use.
Phase II Report: The Floodplain Management System Model.
Phase III Report: Computer Listings for the Floodplain System Model

by Reuben N. Weisz and John C. Day, A report submitted to the U.S. Army Engineer Institute for Water Resources, Fort Belvoir, Virginia, 1973.

At least, the Phase II Report should be published by the National Technical Information Service of the Department of Commerce, Springfield, Virginia, by the summer of 1974.

Contact James Tang, Institute for Water Resources, U. S. Army Corps of Engineers, Kingman Building, Fort Belvoir, Virginia for further information on the availability of all reports.

PROGRAM IDENTIFICATION

Program Title: Land Use - Benefit

Code Name: 761-G1-M3170

Subject: Urban land-use demand is developed by residential activity; then in conjunction with industrial and agriculture, demand is allocated over available space.

Writer: James E. Warren Date: Aug 72, oper. Jan 73

Language: FORTRAN IV

Organization: Project Evaluation
USAED Galveston
P. O. Box 1229
Galveston, Texas 77550

Availability: ADP Center
USAED Galveston
P. O. Box 1229
Galveston, Texas 77550
Restrictions: None

Previous Applications: The program was used in the Galveston Bay portion of Texas Coast Hurricane Study.

Abstract: The land-use benefit program is divided into three parts. Part one of the program develops residential demand comprising single family housing, multifamily housing, commercial, light industry, open space, and highway right-of-way. Population projections and comparable census tract data are used in developing the demand for each type of residential activity. The residential activity demand schedules are aggregated to develop the total urban demand in acres for part one of the program.

Part two of the program utilizes the urban demand from part one and the input of industrial and agriculture demand in acres. In addition, an exclusion acre variable is introduced to provide for floodplain management and other considerations. The exclusion acre variable reduces the amount of available land for development. After reducing the total acreage, the three demand schedules are allocated to the available land,

in 10-year intervals for a maximum of twelve periods. If the demands exceed the supply on a 10-year interval, then the allocation reverts to a one-year interval until saturation occurs.

Part three of the program utilizes the projected allocated land demands from part two of the program for urban, industrial, and agriculture, and, in addition, uses damages prevented, projected income, and agriculture farm values to derive projected benefits for various plans or conditions considered.

Evaluation: The land-use benefit program was designed for use with hurricane and flood control studies. The lowest unit of land use is census tracts, with an upper limit of aggregated regional data.

Areas of Application in Urban Studies: The program may be used in formulation and evaluation of alternative waste water management plans and alternative flood control, floodplain management plans.

TECHNICAL DESCRIPTION

Methodology: The land-use benefit program is written in FORTRAN IV.

Input Data Required:

(1) Number acres (tracts).

(2) Time periods (years).

(3) Population projection factors.

(4) Personal per capita income.

(5) Value of farm products sold.

(6) Census tract population.

(7) Census tract total housing count.

(8) Floodplain housing count.

(9) Census tract single family housing count.

(10) Census tract multifamily unit count.

(11) Acres in floodplain.

(12) Acres in agriculture land.

(13) Title data each plan.

(14) Urban average annual damages each plan.

(15) Industrial average annual damages each plan.

(16) Agriculture average annual damages each plan.

Output Provided:

(1) Table of projected urban demand in acres for single family and multifamily residential, commercial, light industry, open space, and highway rights-of-way.

(2) Table of allocated urban, industrial, and agriculture acres for each plan considered.

(3) Table of projected benefits from damages prevented for urban, industrial, and agriculture.

(4) In addition to printer output in (3) above, the data are loaded on tape 3 and used as part of the input required for program 761-G1-M3180 average annual equivalent benefits.

OPERATING DESCRIPTION

Characteristics: Run time .15 hrs avg. (based on 37 areas)

Hardware Requirements:

Computer Systems Used: The program was written for Honeywell G 225 batch mode.

Peripherals Required: Card reader, printer, 2 tape handlers.

Memory Requirements: 16K words

Software Requirements:

No references or documentation available at this time.

PROGRAM IDENTIFICATION

Program Title: HEC-2 Water Surface Profiles

Code Name: HEC-2 (Computer Program No. 723-X6-L202A)

Subject; Flood zone planning

Writer: Bill S. Eichert Date: Original - December 1968
Updated - August 1971
New Printing - February 1972

Language: FORTRAN II (except input and output instructions for tape units use FORTRAN IV)

Organization: U. S. Army Corps of Engineers
Hydrologic Engineering Center (HEC)
609 Second Street
Davis, Calif. 95616

Previous Applications: This program is used widely throughout the Corps of Engineers to obtain water surface profile data.

Abstract: The HEC-2 water surface profile program computes steady flow profiles for river channels of any cross section for either supercritical or subcritical flow conditions. Special consideration is given to bridges, culverts, weirs, embankments, and dams. The program allows variable roughness, islands, bends, levee overflow, river confluences, and waterfalls. Channel roughness can be established from known highwater marks if desired.

The most recent addition to the program is a routine for determination of encroachments for floodways for the Type 15 Flood Insurance Studies. Input may be in either English or Metric Units.

A data edit program (Program No. 723-G1-L202C) which reads the data cards for the subject program (723-X6-L202A) and checks the data for various input errors is also available.

(This program is an expanded and modified version of program 723-G2-L214A, Backwater - Any Cross Section, which is available from HEC for use on smaller computers.)

Evaluation:

(1) Strengths: HEC-2 is a powerful tool for those actively involved in a floodplain delineation. In addition, a wide variety of flow conditions are allowable when determining water surface profiles.

(2) Usefulness: HEC-2 uses river flow and river characteristics to model the flow of water through a network of rivers and streams. The model is, therefore, equally applicable in urban areas where open channels exist.

(3) Limitations of Use: A user of this program should be well versed in water surface profile computations. The preparation of input with a variety of options is an assest to the experienced user, but a hindrance to the beginner. Training sessions are provided for Corps of Engineer employees and those of cooperating agencies.

Areas of Application in Urban Studies: Floodplain management and delineation; flood predictions (Sections 4.5, 4.6a, 4.7, 5.3f, and 5.4a of "Urban Studies Program - Study Procedure," dated 1 April 1973).

TECHNICAL DESCRIPTION

Methodology:

(1) Basic Theory: The computational procedure is similar to Method 1, Backwater Curves in River Channel, Engineering Manual 1110-2-1409, U. S. Army Corps of Engineers, 7 December 1959. This method applies Bernoulli's Theorem for the total energy at each cross section and Manning's formula for the friction head loss between cross sections. In the program, average friction slope for a reach between two cross sections is determined in terms of the average of the conveyances at the two ends of the reach. Other losses are computed using one of several methods. The critical water surface elevation corresponding to the minimum specific energy is computed using an iterative process.

(2) Computational Methods: For all normal cross sections, the standard step method is used to determine the depth at the next section. Subcritical computations proceed upstream and supercritical computations downstream. Three options are available for starting conditions: known depth, critical depth, and given energy slope. In addition to friction losses, expansion and contraction losses are evaluated at each cross section. Bridges and similar structures can be evaluated by either a normal or special bridge routine. The normal bridge routine considers the bridge the same as any other corss section except that the area and wetted perimeter for the section are corrected due to the bridge structure. The special bridge routine evaluates losses for low flow, pressure flow, and weir flow, or possible combinations of these. Common weir and pressure (orifice) flow relations are used, with applicable coefficients specified by the

user. Bridge computations involving critical or super-critical flow are analyzed according to the principle of conservation of momentum.

Special flow geometries involving levees are considered. The user can either allow or prevent the use of flow area behind a levee based on his knowledge of the flow conditions at the beginning or ending points of the levee, overtopping, breaks, etc. In addition, the effective area of a cross section may be reduced by encroachments and sediment deposition.

The entire river cross section is divided into three regions: left overbank, channel, and right overbank. The discharges in these regions are determined separately, and a discharge-weighted velocity head is calculated for the entire section.

If large changes in velocity occur from section to section, the user may allow the program to insert up to three interpolated cross sections between the actual cross sections. The interpolated sections are geometrically similar to the latest cross section used by the program, but shifted in elevation and proportioned in lateral stationing. The shift in elevation is based on minimum elevations in the respective past and present actual cross sections. The ratio applied to the lateral stationing is that of the area of the channel flow in the previous section to the area of the channel flow in the present section where the depth of the flow is the same. The geometry determined is then used as the interpolated cross section to reduce the large velocity change that previously occurred. The user is cautioned not to compare various profiles determined by the differing interpolated cross sections that are inserted by the routing. The user should note the need for additional cross sections and rerun the profile, supplying additional ground cross sections as required to eliminate computer-inserted interpolated sections.

Input Data Required: Data are input using the following cards:

(1) Cards for Basic Applications
- (a) Cards T1 through T3 - Title cards for output title.
- (b) Card J1 - Job card specifying starting conditions and program options for the job.
- (c) Card NC - Manning's "n" and the expansion and contraction coefficients for transition losses.
- (d) Card X1 - Specifies the geometry of each cross section and program options applicable to that cross section.

(e) Card GR - Specifies the elevation and station of each point in a cross section used to describe the ground profile. The points outside of the channel determine the subdivision of the cross section which corrects for the non-uniform velocity distribution.

(f) Card EJ - Required following the last cross section for each job.

(2) Multiple Profiles, Summary Printout (Cards J2 and J3)

(3) Optional Cards for Roughness Descriptions

(a) Card J2 - Specifies the factor by which to multiply all Manning's "n" values.

(b) Card NH - Used to permanently change the overbank roughness coefficients to values which vary with the horizontal distances from the left side of the cross section.

(c) Card NV - Used to change the channel roughness coefficient, "n," based on water surface elevations.

(4) Optional Cards for Specifying Discharge

(a) Card J1 - Specifies a factor by which to multiply all flows.

(b) Card X2 - Specifies a value of the new flow in the river.

(c) Card QT - Specifies a table of flows for use in computing a series of water surface profiles.

(5) Bridge Losses Cards X2, BT, SB - Cards for including data input necessary when using the special bridge routine. Examples of the input data are drag coefficient for computing pier losses, minimum roadway elevation, and coefficient of discharge "C" for use in weir flow equation.

(6) Specification of Ineffective Flow Areas (Cards X3 and ER)- Contains information on the channel in which the water flows.

(7) Direct Solution for Manning's "n" (J1 and X2 cards) - Cards for computing Manning's "n" from known highwater marks.

(8) Additional Ground Points (Card X4) - Provides added information on the ground profile on the cross section.

(9) Plots of Cross Sections and Profiles (Cards J2 and X1).

(10) Traces and Data Printout (Cards J1, X2, and J2) - Contains information on elevations and cross-sectional traces.

(11) Data Comment Cards.

(12) Critical Depth Option (Card J2) - Contains instructions relevant to the computation of critical depth.

(13) Channel Modification Due to Excavation (Cards J2 and C1) - Allows for modification of the existing channel cross section through excavation of a trapezoidal channel.

(14) Storage - Discharge Output (Card J4) - This optional card provides punched cards for routing by Modified Puls using program HEC-1. This can also be done by a new program, "ROUTE."

Output Provided: The following output data are provided for each cross section, as appropriate:

(1) Depth of flow.

(2) Water surface and mean energy gradient elevations.

(3) Mean velocity head.

(4) Energy loss data.

(5) Total flow.

(6) Amount of flow in left overbank, right overbank, and channel.

(7) Cross section area of left overbank, right overbank, and channel.

(8) Cumulative volume of water in the river since the first cross section.

(9) Cumulative top area of the river since the first cross section.

(10) Travel time from first cross section to present cross section.

(11) Mean velocity in right overbank, left overbank, and channel.

(12) Manning's "n" for left overbank, right overbank, and channel area.

(13) Weighted value of Manning's "n" for the channel based on the distance between cross section, used when computing Manning's "n" from highwater marks.

(14) Minimum elevation in the cross section.

(15) Slope of the energy grade line.

(16) Distances in the left overbank, right overbank, and channel between the previous cross section and the current cross section.

(17) Number of trials required to:
(a) Balance the assumed and computed water surface elevations.
(b) Determine critical depth.
(c) Determine the water surface elevation by the slope area method or to balance the energy gradient in the special bridge routine.

(18) Area of the bridge deck subtracted from the total cross-sectional area in the normal bridge routine.

(19) Cross-section width at the assumed water surface elevation.

(20) Energy grade line elevations computed assuming either pressure flow or low flow control.

(21) Drop in water surface elevation from upstream to downstream sides of the bridge computed using Yarnell's equation assuming Class A low flow.

(22) Total weir and pressure flow at the bridge.

(23) Elevations of the bridge low chord and top of roadway.

(24) Net area of bridge opening below the low chord.

(25) Types of controlling flows.

(26) The stations where the water surface intersects the ground on the left and right sides.

(27) Left and right bank elevations.

Additional details on some of the above items will be printed out when the summary printout option is used.

OPERATING DESCRIPTION

Hardware Requirements:
Computer Systems Used: This program was written for use on the CDC 6600 computer, but may be used with minor modifications on other high-speed computers having four or more magnetic

tapes plus input and output units such as the IBM 360, IBM 7094, and GE 437.

Computer Memory and Speed Requirements: The following tabulation shows an approximate comparison of memory requirements and speeds for various computers.

COMPUTER MEMORY AND SPEED REQUIREMENTS

Computer	Memory Requirement words	Speeds Compile	Speeds Execute Tests
1. CDC 7600	56,000	8 sec	2 sec
2. CDC 6600	60,000	59 sec	15 sec
3. UNIVAC 1108	52,000 (56,000 w/o overlay)	60 sec	50 sec
4. GE 437	29,000	10.0 min	5.0 min
5. IBM 360	70,000 (280,000 bytes)	14.5 min	1.7 min

Software Requirements: References and User Manuals:

(1) U. S. Army Corps of Engineers, "HEC-2 Water Surface Profiles Users Manual," The Hydrologic Engineering Center, Computer Program 723-X6-L202A, February 1972.

(2) U. S. Army Corps of Engineers, "HEC-2 Water Surface Profiles Programmers Manual," The Hydrologic Engineering Center, Computer Program 723-X6-L202A, June 1973.

PROGRAM IDENTIFICATION

Program Title: Urban Stormwater Runoff

Code Name: STORM

Subject: Computation of quantity and quality of urban stormwater runoff

Writer/Organization: Initial program by Water Resources Engineers of Walnut Creek, California, while under contract with The Hydrologic Engineering Center (HEC), Davis, CA. Modifications since January 1973 are by HEC.

Date: January 1973 (original)
Janaury 1974 (1st revision)

Language: FORTRAN IV

Availability: U. S. Army Corps of Engineers
The Hydrologic Engineering Center
609 Second Street
Davis, CA 95616

Previous Applications: Castro Valley, CA; Boise, ID; and Framingham, MA

Abstract: Urban runoff quantity and quality can be analyzed on a continuous (hourly) basis by STORM. The purpose of the analysis is to aid in the selection of the storage capacities and treatment rates required to achieve the desired control of urban stormwater runoff. The model considers the interaction of six stormwater elements: rainfall, runoff, accumulated pollutants, storage capacity, treatment rate, and overflow (from storage). In this approach, dust and dirt and the associated pollutants are washed from the watershed into gutters and storm sewers. The resulting stormwater runoff is diverted (for treatment) at rates not exceeding the specified treatment rate. Runoff in excess of the treatment rate is diverted into storage for subsequent treatment. Runoff in excess of both the treatment rate and storage capacity (overflow) is diverted directly into receiving waters. The quantity and quality of this untreated overflow (for each combination of storage capacity and treatment rate) is assessed.

Recently added changes to the program include the ability to read in an observed hydrograph (or hydrograph computed by

another program) and the effect of snowmelt in the quantity analysis, and the ability to compute soil erosion.

Evaluation:

(1) Strengths: A noteworthy strength of the model is the default option for determining the quality of urban storm runoff when adequate model calibration data are not available. The model is relatively simple and provides the unique capability of processing a continuous record of many years of hourly precipitation data.

(2) Weakness: The modified "rational" formula used in the runoff portion may not be adequate under some conditions.

(3) Usefulness: The model is generally applicable for use in the planning phase (survey scope) of urban studies.

(4) Limitations: Since the model does not consider routing it may not produce properly shaped hydrographs and may not be applicable to large areas. In studies where the emphasis is placed on predicting and accounting the volume of runoff and the associated pollutants, this may not be a serious limitation.

Areas of Application in Urban Studies: This model does not provide as much detailed output relevant to urban runoff as the more elaborate models. The model would be useful in providing generalized information for planning Corps projects involving the control of urban stormwater runoff. (Sections 4.4, 4.6, 5.2f, 5.3, 5.4, of Urban Studies Program - Study Procedure, dated 1 April 1973.

TECHNICAL DESCRIPTION

Methodology:

Computation of Runoff Quantity - Runoff is calculated on an hourly basis by the following expression:

$$R = C(i-f) \qquad (B1)$$

where

R = runoff rate in inches per hour
C = composite runoff coefficient
i = rainfall rate in inches per hour
f = available depression storage in inches per hour

Potential evaporation (an input variable) and antecedent rainfall are used to calculate the available depression storage (f) by the following expression:

$$f = f_o + N_D k, \; f < F \qquad \text{(B2)}$$

where

f_o = available depression storage in inches at end of the previous rainfall

N_D = number of dry days since previous rainfall

k = depression storage recovery factor (evaporation) in inches per day

F = maximum available depression storage in inches

Computation of Runoff Quality - The quality of runoff is based on the accumulation and washoff of dust and dirt and the associated pollutants. Five water-quality parameters are predicted by STORM: suspended solids, settleable solids, BOD, total nitrogen, and dissolved orthophosphate. More parameters can be added when field data become available for use in calibration. STORM maintains a continuous accounting of the accumulation of these five pollutants on the watershed as well as the amount that is "washed off" during each runoff event. The program computes concentrations of the pollutants based on the pounds of pollutants washed off the watershed and the volume of water that runs off. The program then proceeds to the storage-treatment rate accounting and the quantitative assessment of the amount of overflow of pollutants from storage. All parameters are assumed to be conservative.

The procedures and equations used for the computation of runoff quality are essentially the same as those contained in EPA's Storm Water Management Model.

Input Data Required:

Hydrological Data:

(1) Hourly precipitation data for as many years as are required in the analysis (days on which precipitation occurred).

(2) Normal arrival precipitation for the watershed and the precipitation station.

(3) Surface depression storage (inches) for the urban and nonurban portions.

(4) Runoff coefficients for the impervious and pervious parts of the urban portion and the runoff coefficient for the nonurban portion.

(5) Potential evaporation in inches per day for each month of the year for the urban and nonurban portions.

(6) Mean daily or max/min air temperatures for the period corresponding to the precipitation record.

Land-Use, Related Data: The following matrix of information is required for each watershed on which STORM is to be used. In addition, the street sweeping efficiency is also required.

Land Use	Percent of Area in Land Use	Percent Impervious	Street Gutter Density (Ft/Acre)	Street Sweeping Interval (Days)
Single Family				
Multi-family				
Commercial				
Industrial				
Open (parks, etc.)				

Water-Quality Data: If water-quality data are available, they can be used to verify coefficients for the various pollutant constituents used in the model. If no water-quality data are available, the program will supply default values.

Output Provided: The printed output includes a listing of the hourly rainfall data, the input quality parameters, and the input land-use data. The computed output is presented in three sections: (1) quantity analysis, (2) quality analysis, and (3) detailed (hourly) analysis of selected events (pollutographs).

The quantity analysis includes a one-line listing of each event (an event being defined as any time storage is utilized) showing: (1) the duration and amount of rainfall, (2) the amount of runoff, (3) the quantity and number of hours of treatment, (4) the duration of storage, (5) ages of storage, (6) ages of storage based on inlet and outlet configurations, (7) the amount of overflow to receiving waters, and (8) the amount of overflow in the first X number of hours (X is specified by the user or defaulted to 3). A summary showing the above information on an average annual basis for overflow and nonoverflow events is also provided. A dimensionless storage utilization curve is plotted showing the percent of time various levels of storage were utilized. These plots indicate the "efficiency" of the particular storage-treatment rate combination.

The quality analysis includes a one-line listing of each event showing: (1) the quality of runoff, (2) the quality of overflow, and (3) the quality of overflows during the first X hours of overflow.

The third section of output includes a detailed (hourly) listing of selected events showing: (1) the date and time of the event, (2) the quantity of rainfall and runoff, (3) the amount of each pollutant washed off during each hour of the event, and (4) the concentrations of pollutants in the runoff water.

OPERATING DESCRIPTION

Characteristics: Computation time is quite variable and is a function of the storage-treatment rate combination and the number of rainy days to be analyzed. Initial runs required from 12 to 56 seconds of Univac 1108 time per 1000 rainy days per storage-treatment rate combination depending on the storage and treatment rate used. Smaller treatment rates cause the computation times to increase dramatically.

Hardware Requirements:

Computer Systems Used: The present version of the program will operate on a Univac 1108. The program will be modified to operate on the IBM 360-50 and the CDC 7600. A FORTRAN IV compiler and the ability to print output tapes is required on systems other than the Univac 1108.

Peripherals Required: The program requires three tape disk units in addition to the line printer and card reader. If the rainfall data are to be input on tape/disk, a fourth tape/disk unit is required.

Memory Requirements: About 35,000 words of core are required for the Univac 1108.

Software Requirements: References and User Manuals:

(1) U. S. Army Corps of Engineers, "Urban Runoff: Storage, Treatment and Overflow Model 'STORM'," The Hydrologic Engineering Center, Computer Program 723-S8-L2520, (currently undergoing revision).

(2) Office of the Chief of Engineers (DAEN-CWE-Y), "Urban Studies Program, Management of Urban Stormwater Runoff," Engineer Technical Letter No. 1110-2-515, 28 February 1974, Washington, D. C.

PROGRAM IDENTIFICATION

Program Title: HEC-1 Flood Hydrograph Package

Code Name: HEC-1 (Computer Program No. 723-X6-L2010)

Subject: Flood zone planning; flood routing; rainfall/runoff phenomena

Writer: Leo R. Beard   Date: (Original) October 1970
(Updated) January 1973

Language: FORTRAN IV

Organization: U. S. Army Corps of Engineers
Hydrologic Engineering Center
609 Second Street
Davis, CA 95616

Availability: The Hydrologic Engineering Center

Previous Applications: This program is used widely throughout the Corps of Engineers for making flood hydrograph computations.

Abstract: Most ordinary flood hydrograph computations associated with precipitation and runoff on a complex, multisubbasin, multichannel river basin can be accomplished with this package. Precipitation patterns must be related to a single hypothetical or recorded storm as there is no provision for precipitation loss rate recovery during periods of no precipitation.

HEC-1 is capable of performing the following five major types of flood hydrograph analysis:

(1) Optimization of routing parameters.

(2) Optimization of unit hydrograph and loss rate parameters.

(3) Generalized precipitation, runoff, routing, and combining operations to simulate the hydrologic response of a watershed and its stream network.

(4) Stream system computations for specified precipitation depth-area storm relations for the entire watershed or region.

(5) Streamflow network simulation relative to multiple floods for multiple plans of basin development and the economic analysis of flood damages.

Several small component programs are available and may be employed for any particular study in lieu of the larger multipurpose program, HEC-1. The number and titles of these programs are:

(1) L2230 Unit Hydrograph and Loss Rate Optimization.

(2) L2260 Basin Rainfall and Snowmelt Computation.

(3) L2280 Unit Graph and Hydrograph Computation.

(4) L2310 Streamflow Routing Optimization.

(5) L2320 Hydrograph Combining and Routing.

(6) L2370 Balanced Hydrograph.

The methodology used in these programs is basically the same as described below for HEC-1.

Evaluation:

(1) Strengths: This program has many desirable features, the most important being its ability to execute a variety of computational procedures in a single computer run, yet be contained within a reasonable amount of computer core storage. The relative compactness of the program is quite advantageous, since the amount of storage required is a significant factor in determining whether or not the program can be used for a particular purpose.

(2) Weaknesses: HEC-1 does not adequately model runoff from impervious areas. Also program modifications are needed to include closed conduit flow and gutter and pressure flow networks. The original development of the program was flood hydrograph studies in nonurban areas.

(3) Usefulness: HEC-1 would be useful in modeling the rainfall/runoff phenomena in urban areas with an open channel drainage system or where closed channels can be simulated by a storage routing method.

(4) Limitations of Use: An important limitation is that the Flood Hydrograph Package is applicable only to single storm analyses. This affects only the precipitation and loss rate computations, as no provision is made for recovery of loss rate potential during periods of no precipitation.

Areas of Application in Urban Studies: Flood predictions; major drainage system design; evaluation of reservoir and channel development plans; flood damage computations (sections 4.4, 4.5a, 4.6a, 5.2f, 5.3f, 5.4, and 5.5 of Urban Studies Program Study Procedure, dated 1 April 1973).

TECHNICAL DESCRIPTION

Methodology: The equations and computational procedures used in the Flood Hydrograph Package are discussed in paragraph 6 of the HEC-1 users' manual. Background material on flood hydrograph analyses can be found in EM 1110-21405. Modeling of a basin consists of describing the topologic structure of the basin (drainage basin boundaries, stream channels, and the logical relationships between the drainage areas and stream channels) and defining the parameters that describe the precipitation-runoff response of the subbasins and channels that comprise the river basin. The package performs numerous computations as summarized below.

(1) Precipitation: The precipitation applied to a subarea for runoff computations may be determined by three methods: (a) nonrecording and recording station data, (b) basin mean precipitation, and (c) standard project or probable maximum hypothetical precipitation distributions.

(2) Snowfall and Snowmelt: Where snowfall and snowmelt are considered, there is provision for separate computation in up to ten elevation zones. These zones are usually considered to be in elevation increments of 1000 feet but any equal increments of elevation can be used as long as the air temperature lapse rate corresponds to the change in elevation within the zones.

Precipitation is assumed to fall as snow if the zone temperature is less than the base temperature plus two degrees. Melt occurs when the temperature is equal to or greater than the base temperature. Snowmelt is subtracted and snowfall is added to the snowpack in each zone.

Snowmelt is computed by the degree-day or energy-budget methods. The basic equations for snowmelt computations are from ER 1110-2-1406.

(3) Loss Rates: Loss rates are computed using initial and uniform losses or by a function which relates loss rates to rainfall and snowmelt intensity and to accumulated loss (ground wetness).

The snowmelt computations are performed for each elevation zone that has melting snow. If rain is falling in an elevation zone which has no snow, the rain losses are computed by two different equations depending upon the duration of the total flood event.

(4) Unit Hydrograph: If the unit hydrograph is not provided, it is computed by the Clark Method to conform to specified Snyder or Clark coefficients.

(5) Base Flow and Recession: Base flow is described by an exponential recession of the flow from preceding runoff. The hydrograph, if not supplied directly, is computed by the unit hydrograph technique, adding computed runoff to base flow. When this total is below a recession threshold flow, it is not permitted to recede faster than the original computed base flow recession rate.

(6) Routing: The routing procedures using the Package are described in EM 1110-2-1408, in "Streamflow Synthesis and Reservoir Regulation" by Rockwood for multiple storage, and in Handbook of Applied Hydrology, by Ven Te Chow. The following routing procedures are included in the program:

(a) Modified Puls.

(b) Muskingum.

(c) Working R and D.

(d) Straddle - Stagger.

(e) Tatum.

(f) Multiple Storage.

(7) Unit Hydrograph and Loss Rate Criteria: HEC-1 has the capability to automatically determine a set of unit hydrograph and loss rate parameters that "best" reconstitutes an observed runoff event for a subbasin given the average rainfall for the subbasin, the drainage area, and a few runoff hydrograph parameter values for starting flow and base flow recession computations. The "best" reconstitution is considered to be that which minimizes the weighted squared deviations between the observed hydrograph and a reconstituted hydrograph. The optimization procedure used to derive values for the variables is the univariate gradient

search procedure. A detailed description of the procedure is contained in Optimization Techniques for Hydrologic Engineer, by Leo R. Beard.

(8) Hydrograph Balancing: A hydrograph balance routine is included to convert any given hydrograph to one having specified volumes within given durations.

(9) Stream System: One of the more difficult problems of hydrologic evaluation is the successive evaluation of many storm centerings upstream of each location of interest. Precipitation must be distributed throughout the basin in such a manner that the runoff generated by each subarea tributary to the location of interest within a basin is consistent with the runoff contributed by the other subareas, including the subarea on which a project may be located. If a simple distribution scheme has not been devised, a great many storm centerings must be evaluated for each successive downstream location. Consistency between successive downstream hydrographs can be maintained by generating each from rainfall totals that correspond to a specific subbasin size and a specific precipitation depth-drainage area relationship. Since the average depth of precipitation over a tributary area for a storm generally decreases with the size of contributing area, it would ordinarily be necessary to recompute a decreasing consistent-flood quantity contributed by each subarea to successive downstream points. In order to avoid the proliferation of hydrographs that would ensue, the stream system procedure for HEC-1 makes use of a number of hydrographs (termed "index hydrographs") computed from a range of precipitation depths throughout the river basin complex. The index hydrographs are computed from a set of precipitation depth-drainage area (index area) values, a time distribution of rainfall pattern, and appropriate loss rate and unit hydrograph parameters. The hydrograph at any stream location is then computed by interpolating the index hydrographs relative to the total tributary area upstream of that.

(10) Multiple Plan: Ratio Analysis with or without Economic Analysis. HEC-1 can evaluate the economic consequences for a number of plans of proposed basin development. A plan can be postulated as one which changes either the runoff hydrograph or the exceedence frequency-flow damage relations. The runoff hydrograph is determined by the parameters that model the watershed's response to a storm. Any alteration of these parameters, such

as a change in unit hydrograph or loss rate coefficients, or routing criteria, can produce a different runoff hydrograph and be evaluated as a plan of development. The usual application is to evaluate the effects of a number of storage reservoir proposals, channel modifications, or combinations of these.

The peak flow is used as the index of flood severity that best relates damages to flood events. The relationship is in the form of flow and the corresponding damages for each of a number of categories of damages. Flow damage relations can change between postulated plans of development as a result of channel modification altering the rating curve. The change in the exceedence frequency relation that is the result of changes in runoff characteristics is accomplished automatically. The flow damage relations are merged with flow-exceedence frequency curve of damages. This function is then integrated to yield the final evaluation which is the expected value of annual damages.

(11) Graphical Display: A subroutine in the program is especially designed for the flood hydrograph package to provide a user-controlled plot of selected output on the printer. Items to be plotted are presented in the program. The subroutine is available in both 121- and 132-column printer versions.

Input Data Required: Due to the many capabilities of the program, the input data requirements are rather complex. Input data cards are described in detail in Addendum 6 of the users' manual. The type of information contained on the data cards is summarized below:

Card Code	Card Contents
A	Job title
B	Job specifications
C	Observed hydrograph to be reconstituted
D	Routing optimization criteria and observed inflow hydrograph
E,F	Unit graph and loss rate optimization criteria
G,H	Station precipitation data for all subbasins of the watershed

Card Code	Card Contents
I	Precipitation depth-drainage area data
J	Multiflood, multiplan data
K	Computation specification for model building
L	Hydrograph balancing criteria
M-X	Subarea runoff computation data including precipitation, losses, and unit graph information
Y	Individual reach routing criteria
Z	Economic and flood frequency data

In addition to the above punched card data, it is possible to input known (previously computed) hydrographs from a tape or disk device at any point in the stream network computations.

Output Provided: For optimization jobs, the best fit values of the variables are printed along with an interval-by-interval listing of the precipitation, losses (inflow and storage for routing), and computed and observed discharges. In the process of modeling a watershed, the program provides output with respect to the precipitation, rainfall and snowmelt losses, and excess unit hydrographs, subbasin outflow hydrographs, routed hydrographs, and combined hydrographs. Graphical display of intermediate or summary hydrographs and precipitation can be called where desired. Summary printout shows the runoff, routing, and combining operations for each stream station. There are print and plotter controls which govern the amount of detail in the output. The stream system computation procedure includes computations for a maximum of five base floods in a similar fashion to the general watershed model for each flood. An interpolated hydrograph is printed for each stream station based on the size of the area tributary to that point.

The multiplan economic analysis procedure provides output similar to the general watershed model for each of the multiple floods. Average annual damages are provided for each damage center for each plan of development as well as for existing conditions.

OPERATING DESCRIPTION

Characteristics and Hardware Requirements: This version of the Flood Hydrograph Package has been developed and tested primarily on the Univac 1108 and the Control Data Corporation 6600 computer systems. It was then adapted for use on the GE 400 series computers. The following tabulation shows the hardware and software requirements and selected running times for the program.

HARDWARE/SOFTWARE REQUIREMENTS AND RUNNING TIME

FORTRAN IV Compiler
Four Tape and/or Disk Units*

		Univac 1108	CDC 7600	GE 400**
Memory (words)		38,700	35,400	32,000
Printer (positions)		132	132	120
Compilation (CPU seconds)		30	3	
Execution† of:	Test 1	9		
(CPU seconds)	Test 2	90	12	
	Test 3	5		
	Test 4	4		
	Test 5	12	1	
	Test 6	9		
	Test 7	14		

* May only require two tapes or disks if output hydrographs are not to be saved or read in from previous jobs.
** Requires special deck with reduced dimensions.
† Descriptions of the above listed tests are as follows:

Test 1 - Optimization of loss rate and unit hydrograph parameters relative to reconstituting a hydrograph from rainfall.
Test 2 - Optimization of loss rate and unit hydrograph parameters relative to reconstituting a hydrograph from snowmelt and snowfall.
Test 3 - Optimization of routing parameters for the muskingum method from known upstream and downstream hydrographs.
Test 4 - Balance a hydrograph to yield specified flow duration characteristics.
Test 5 - Compute runoff hydrographs throughout a stream network.
Test 6 - Compute runoff hydrographs throughout a stream system which are consistent with a specified depth-area relationship.
Test 7 - Compute hydrographs for multiple plans of basin development and evaluate average annual benefits for each plan.

Software Requirements: References and User Manuals:

(1) U. S. Army Corps of Engineers, "HEC-1 Flood Hydrograph Package Users Manual," The Hydrologic Engineering Center, Computer Program 723-X6-L2010, January 1973.

(2) U. S. Army Corps of Engineers, Engineering and Design, Flood Hydrograph Analyses and Computations, EM 1110-2-1411, 13 August 1959.

(3) U. S. Army Corps of Engineers, Engineering and Design, Standard Project Flood Determinations, EM 1110-2-1411, 26 March 1952.

(4) U. S. Weather Bureau and U. S. Army Corps of Engineers, Seasonal Variation of Probable Maximum Precipitation East of the 105th Meridian for Areas from 10 to 1,000 Square Miles and Durations of 6, 12, 24, and 48 Hours, Hydrometerological Report No. 33, Washington, D. C., April 1956.

(5) U. S. Army Corps of Engineers, Engineering and Design, Runoff from Snowmelt, EM 1110-2-1406, 5 January 1960.

(6) Clark, C. O.; Storage and Unit Hydrograph, Trans. American Society of Civil Engineers, Vol. 110, pp. 1419-1488, 1945.

(7) Snyder, F. F.; Synthetic Unit Hydrographs, Trans. American Geophysical Union, Vol. 19, Part 1, pp. 447-454, 1938.

(8) Chow, Ven Te, Handbook of Applied Hydrology, McGraw-Hill, New York, 1964.

(9) Rockwood, D. M., Streamflow Synthesis and Reservoir Regulation, U. S. Army Corps of Engineers, North Pacific Division, Portland, Oregon, Engineering Studies, Project 171, Technical Bulletin No. 22.

(10) U. S. Army Corps of Engineers, Engineering and Design, Routing of Floods Through River Channels, EM 1110-2-1408, 1 March 1960.

(11) Beard, Leo R.; Optimization Techniques in Hydrologic Engineering, The Hydrologic Engineering Center, Technical Paper No. 2, 1966.

PROGRAM IDENTIFICATION

Program Title: Cross-Section Overlay for Improved Channel Program

Code Name: 722-F6-M2330

Subject: Cross section location for flood zone planning

Writers: Donald R. Walker   Date: 1974
William R. Mayfield
Stephen T. Maynord

Language: FORTRAN IV

Organization: U. S. Army Engineer District, Fort Worth
P. O. Box 17300
Fort Worth, Texas 76102

Availability: U. S. Army Corps of Engineers
Waterways Experiment Station
P. O. Box 631
Vicksburg, Mississippi 39180

Abstract: The purpose of the program is to superimpose an improved channel on natural cross sections. This program modifies the x-y points of the cross section. The existing Basin Data File is not disturbed. A new output file is created each time the Overlay Program is run. U.S. Customary units are used in the calculation. A main program must be used to call this subroutine. The improved channel configuration must be symmetrical.

PROGRAM IDENTIFICATION

Program Title: Discounting Future Benefits

Code Name: 761-G1-R3010

Subject: Discounting future growth projections

Writer: M. T. Lazarus

Language: FORTRAN IV

Organization: U. S. Army Engineer District, Jacksonville
P. O. Box 4970
Jacksonville, Florida 32201

Availability: U. S. Army Corps of Engineers
Waterways Experiment Station
P. O. Box 631
Vicksburg, Mississippi 39180

Abstract: The purpose of this program is to discount future growth projections and compute the annual equivalent benefits for all types of future growth. The program utilizes FORTRAN IV for a GE 225 computer. Future growth projections are considered as annuities over the life of the project and their present worth and average annual equivalent are computed.

INPUT - Date and identification, type of growth projection, interest rate, growth period and project life, initial benefit, maximum projected benefit, maximum projected benefit, and output specification. If variable growth is assumed, input includes inflection points on growth curve.
OUTPUT - Input plus average annual equivalent factor and benefit; in addition, annual values of unit benefits, actual benefits, and the summation of the present worth of the benefits printed if specified.

PROGRAM IDENTIFICATION

Program Title: Crop Damage From Multiple Floods Per Year

Code Name: 761-G1-A4010

Subject: Calculation of crop damage from multiple floods per year

Writers: Walter T. Miller   Date: 1975
George C. Cummins

Language: FORTRAN IV

Organization: U. S. Army Engineer District, Vicksburg
P. O. Box 60
Vicksburg, Mississippi 39180

Availability: U. S. Army Corps of Engineers
Waterways Experiment Station
P. O. Box 631
Vicksburg, Mississippi 39180

Abstract: The program is written in FORTRAN II for the G225 and FORTRAN IV for the G400 series computer. The method used is sometimes called the historic method because floods of record and season-crop damage factor curves are used in the computations. Percentage loss from flood damages is computed from a set of four curves. The sum of these percentages is multiplied by the weighted cost per acre times the cleared acres flooded to get the flood damage. The historic file is limited to 300 floods on the G225 and 400 floods on the G437. Floods per crop year are limited to 15 floods of descending order. Program is set up for 10 crops in the Vicksburg District area. These can be changed for any area. Acres flooded is limited to largest integer accepted by the computer.

Input consists of 8 types of cards in the following sequence:

(1) A deck of 48 cards to load the crop curve data.
(2) Comment card (optional).
(3) Title card (one per flood deck).
(4) Flood card (one per flood).
(5) End card (one at the end of the flood deck).
(6) Crop index card (one per kind of crop flooded).
(7) New title card (optional).
(8) End card (one at the end of the crop cards; input may be continued at (2) above).

All flood data (type (4) cards) are read together to make the history deck.

Output gives:

(1) Program number.
(2) Comment cards (first sheet of output only).
(3) Recap of crop index card.
(4) Title card and page number (follows crop recap and at the top of each page).
(5) Beginning date of flood and gage height (acres and flood loss if crop damage occurred).
(6) Losses for the year.
(7) Total of losses for the crop for the period of record.

When a flood analysis is run it comes out on the first sheet.

(1) Program number.
(2) Comments cards.
(3) Title card.
(4) Minimum and maximum acres flooded.
(5) Count of floods having 6 different durations occurring during four periods of the year.
(6) Total of floods for each period and the period of
record. record.

Wilmington District has a version of this program that bands the area flooded. In that locality the value of crop loss varies greatly depending on the contour of the flood plain.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

LaGarde, Victor E
Plan for development of systematic procedures to aid Corps Districts in flood damage calculations / by Victor E. Lagarde. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1979.
79, [57] p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; EL-79-3)
Prepared for Office, Chief of Engineers. U. S. Army, Washington, D. C.
Includes bibliographies.

1. Estimating. 2. Flood damage. I. United States. Army. Corps of Engineers. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; EL-79-3.
TA7.W34 no.EL-79-3